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CONTENTS

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BULLETIN NO. 102

JANUARY, 1914.

The Morphology of the Sheep Tape-Worm

Thysanosoma Actinioides

(Technical)

By LEROY D. SWINGLE

Bulletins will be sent free upon request. Address Director Experiment Station, Laramie, Wyoming.

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The Morphology of the Sheep Tape-Worm.

Thysanosoma Actinioides

By LEROY D. SWINGLE.

The Fringed Tapeworm of sheep, as it is commonly called, is very prevalent in Wyoming. Most of the sheep slaughtered at Laramie are infected. But in spite of its commonness and the ill effects it produces when present in large numbers, neither its anatomy nor its life-history has been worked out.

Curtice (1890)* has given us the best account of the worm. He made some experiments to determine the method of transmission, but his results were negative. His description of the anatomy of the worm, based on examination of fresh or unstained worms, is more adequate than any other I have seen. Still he did not work out the details of structure as they are to be found in microscopic sections.

In this bulletin I wish to present further details of the morphology. Photographs, which tell more than words, accompany the brief descriptions.

The adult worm varies greatly in length, but is generally not more than 15 inches long. It is characterized by a fringe, which projects from the posterior borders of the segments. In the neck region this fringe is absent. It begins to appear on about the 20th segment. In this region the border is slightly wavy (Fig. 1). On the more posterior segments it appears as scallops (Fig. 2).

*Cooper Curtice. The Animal Parasites of Sheep. U. S. Dept. of Agriculture, Washington, D. C., 1890.

Still farther back the fringe is composed of long, regular papillae (Fig. 3). They are occasionally bifurcated.

The segments are short as compared with their length, except in the posterior region (Fig. 2). There are about five to six hundred segments in a worm a foot long. Each of the more mature segments bears a genital pore on each side. Concretions are present in both the medulla and cortex, especially in the anterior segments. The scolex bears four large suckers. No hooks or rostellum are present (Fig. 1). The neck is very short and hardly apparent.

Four excretory ducts, arising in the scolex, pass backward through the worm in a lateral position. The two ducts nearer the median line (dorsal ducts) are smaller and more convoluted except near the scolex, than the outer (ventral) pair, which become larger toward the middle and posterior portion of the worm. (Fig. 2 and 4). The outer, or ventral, pair are connected in the posterior region of each segment by a cross duct (Fig. 5). Cross sections of the worm near the head show many, about 28, small longitudinal ducts on each side of the medulla at its juncture with the cortex (Fig. 6). No connection between these ducts and the other excretory ducts was found.

In the neck region the ventral excretory ducts each give off at short intervals a duct which immediately bifurcates, one branch passing dorsally and the other ventrally through the medulla and joining the corresponding ducts from the opposite side. These dorsal and ventral branches give off branches to the cortex.

A pair of nerves arise in the scolex and pass backward through the worm in a lateral position. They are very prominent (Figs. 2, 4 and 6), and show no cross branches.

The longitudinal muscles constitute a well developed layer in the parenchyma of the cortex. Figure 7 shows the large fibers as they appear in longitudinal section. In figures 8

and 9, cross sections of a mature proglottis, they are seen to occupy practically all of the cortex. The dorso-ventral muscles are slight and insignificant.

The reproductive system is especially interesting. Yet, as far as I am aware, its morphology has not been worked out in detail. The male and female organs, except the uterus, begin development simultaneously. The uterus does not begin development till the overy is well differentiated.

In the earliest stage of development the position of the ovary, vas deferens and seminal receptacle is indicated by a thickening of the cells (Fig. 4 Ov). This condition occurs in about the 200th proglottis. The testes do not yet appear. But by the time the vas deferens has differentiated from the thickened mass of cells the testes appear (Fig. 10). They lie in the posterior portion of the segment, althrough they may occupy nearly all of the segment until the uterus begins to develop. (Figs. 12 and 13). In respect to dorso-ventral differentiation they occupy the middle of the proglottis and fill the medulla (Fig. 11). Since the ovaries also are median there is strictly no dorso-ventral differentiation.

Efferrent ducts leading out from the testes empty into the vasa efferentia which live in the anterior portion of the proglottis (Figs. 10, vd and 31 ef). In the early stages the vas deferens passes anterior to the ovary (Fig. 10). But when the ovary becomes large, it embraces the vas deferens (Fig. 12). The vas deferens passes in almost a straight line toward the genital pore until it reaches the region of the ventral excretory duct where it becomes sharply convoluted. (Figs. 10 and 12). It then passes through the cirrus sac and opens at the end of the cirrus (Figs. 13, 14 and 15). The last mentioned figure shows the cirrus in the act of emitting sperm cells. The vagina opens into the genital pore alongside the vas deferens (Fig.13). It passes in a more or less straight line to the seminal recepticle which lies in the center of the ovary (Figs. 10, 17, 31). The seminal receptacle is sharply differen-

tiated from the vagina (Figs. 27 and 29). When the ovary is discharging its eggs, the seminal receptacle is found to be filled with sperm cells (Fig. 29.)

After the testes and ovaries have become well developed there appears in the anterior portion of the segment a thickened mass of cells extending from one ovary across the proglottis to the other. Soon, little spaces make their appearance in this mass (Figs. 17 and 18.) These constitute the uterus. Just anterior to and median from the ovary there develops a special chamber in the uterus (Figs. 17 and 20). The oviduct empties into this chamber (Figs. 17 and 20). The fertilized eggs are deposited in this chamber and from it passed into the uterus proper.

The ovary develops into a very regular and spherical mass (Fig. 18). In the center of it just posterior to and on one side of the seminal receptacle, a chamber develops (Figs. 17, 27, 29 and 30). I shall call it the receptaculum ovorum because the eggs from the ovary are discharged into it. (Figs. 29 and 30). From the median side of this chamber the oviduct leads out and passes to the uterus (Figs. 30 and 31). At about its middle point it is joined by the median end of the seminal receptacle (Fig. 31). The receptaculum ovorum at first contains a parenchymatous tissue but as soon as the eggs begin to fill it this tissue disappears (Figs. 17, 27 and 29). The walls of the receptacle of the ovary are contiguous, where the eggs are allowed to enter (Fig. 29 e). The eggs evidently pass out of the receptacle by way of the oviduct and are fertilized in the region of the seminal receptacle. They then pass to the uterus (Fig. 31). The seminal receptacle becomes bent around the receptaculum ovorum so as to form a U-shaped chamber (Figs. 22 and 27). No shell gland or vitelloria could be found. The uterus is continuous from one side of the proglottis to the other. After the spaces, such as are shown in figures 18 and 24, are established, a thickened band of cells appears just anterior

to the spaces (Fig. 18). From this band the uterine pouches soon develop. While this is going on the spaces are being filled with eggs (Fig. 19). The thickened band seems to break up into a comb-like structure, the teeth of which later become tongue-like and the whole structure becomes tortuous (Figs. 21, 23 and 9). Gradually the eggs, which are deposited in the uterus proper arrange themselves in regular columns (Figs. 23, 25 and 28). In cross sections the uterus and its pouches are shown to be convoluted. They are like a pad which is thrown into sharp folds (Fig. 9) This accounts for the appearance one gets in a frontal section where the eggs appear to be in nests capped with the pouches (Figs. 25 and 26.) Curtice (1890) describes the pouches as filled with eggs. I have never found any signs of their filling the pouches, even in the ripest segments. Still the pouches appear as if they ought to open and receive the eggs, although they are always solid masses of tissue.

As development of the uterus proceeds the testes gradually degenerate and the ovary disappears, all of its eggs being extruded. Every vestige of the ovary disappears while the testes are still apparent (Fig. 25). The seminal receptacle persists almost to the last (Fig. 25), but finally when the proglottis is ripe practically all of the structures are gone except the uterus, filled with embryos, and the uterine pouches (Fig. 28).

The relation of all the organs is shown in detail in the drawing (Plate VI, Fig 31).

I am indebted to Dean H. G. Knight for valuable aid in the photography.

EXPLANATION OF PLATES.

A. Anterior.
C. Cirrus.
Cp Cirrus pouch.
Cu Cuticula
d. Longitudinal canals between cortex and medulla.
Dc. Dorsal excretory canal.
e. Eggs.
f. Fringe.
gp. Genital pore.
lm. Longitudinal muscles.
m. Medulla.
n. Nerve.
od. Oviduct.
p. Posterior.
pa. Paranchyma.
ro. Receptaculum ovorum.
rs. Receptaculum seminis.
s. Sperm cells.
sc. Subcuticular cells.
sl Segment limits.
t. Testes.
tc. Transverse Excretory Canal.
up. Uterine Pouches.
ut. Uterus.
va. Vagina.
vc. Ventral excretory canal.
vd. Vas deferens.
ve. Vasa efferentia.
X. Chamber which receives the fertilized eggs from the oviduct.

All the figures are arranged with the anterior end toward the top of the page.

PLATE I.

Fig. 1. Scolex and first segments of the worm.

Fig. 2. Surface view of the worm in the region anterior to the point where the reproductive organs begin to develop. It shows the scalloped stage of the fringe.

Fig. 3. Surface view of the fringe toward the middle of the worm.

Fig. 4. Frontal section in the region where the reproductive organs are beginning to develop.

Fig. 5. Frontal section showing the transverse excretory canals leading off from the ventral canal. The juncture of the canals is shown at vc.

PLATE II.

Fig. 6. Cross section of the worm near the head. At d are shown the longitudinal canals between the cortex and medulla.

Fig. 7. Frontal section showing the longitudinal muscle fibers.

Fig. 8. Cross section of ripe proglottid.

Fig. 9. Cross section of ripe proglottid showing the tortuous condition of the uterus and uterine pouches.

Fig. 10. Frontal section from the anterior portion of the worm. The early stages of development of the reproductive organs are shown.

Fig. 11. Cross section of the worm showing reproductive organs well developed. The testes and ovaries are shown to be neither dorsal nor ventral.

PLATE III.

Fig. 12. Frontal section, showing the testes, ovaries and vas deferens. (Left side of worm.)

Fig. 13. Frontal section of the cirrus pouch and the vagina. (Left side of worm.)

Fig. 14. Frontal section of the cirrus protruded. (Right side of worm.)

Fig. 15. Cirrus in the act of expelling sperm cells. (Right side of worm.)

Fig. 16. Frontal section showing an early stage in the development of the ovary, seminal receptacle and oviduct. The uterus is indicated by a band of thickened cells. (Right side of worm).

Fig. 17. A little later stage than the preceding figure. The uterus appears as cavities in the thickened band cells. The receptaculum ovarum has made its appearance. The oviduct shows plainly. (Right side of worm).

PLATE IV.

Fig. 18. Frontal section showing the repetition of reproductive organs in succeeding proglottids. In this stage the ovary has reached its maximum size and is spherical. The uterine spaces show plainly. (Left side of worm.)

Fig. 19. A later stage in the uterine development than is shown in the preceding figure. The spaces have become more regular and chamber-like and are filled with eggs.

Fig. 20. A little later stage than the preceding. The uterus is broader and the chamberlike arrangement has disappeared. The

principal feature to be noted is the presence of a receptacle in the uterus for the reception of the fertilized eggs. The entrance of the oviduct to the chamber can be seen at **od**. (Left side of worm.)

Fig. 21. This shows the same stage of uterine development as the preceding figure. The thickened band of cells just anterior to the uterus as shown in figure 19 has given rise to a comb-like structure, **up**, which is the beginning of the uterine pouches.

Fig. 22. Enlarged view of figure 25, showing the seminal receptacle at **rs**. On account of its U-shape it appears in two parts. (Right side of worm.)

Fig. 23. Frontal section of the worm where the reproductive organs have matured and the ovary has degenerated. Note the columnar arrangement of the eggs in the uterus. (Left side of worm.)

Fig. 24. Section of the ovary and early uterus. The oviduct passing from the region of the seminal receptacle to the uterus is very plain. (Right side of worm.)

PLATE V.

Fig. 25. Frontal section showing the well developed and filled uterus. The testes are still prominent although the ovary has disappeared. The seminal receptacle persists almost to the last. (Left side of worm.)

Fig. 26. Frontal section of the uterus, showing the nest-like appearance of the uterus due to its convolutions in the plane at right angles.

Fig. 27. Section through the ovary showing the receptaculum ovorum, and the entrance of the vagina into the receptaculum seminis. (Left side of worm.)

Fig. 28. Frontal section of ripe proglottids. Practically the only organ shown is the uterus filled with embryos. (eggs).

Fig. 29. Section through the ovary showing the seminal receptacle engorged with sperm cells. Posterior to it can be seen the receptaculum ovorum filled with eggs that are being discharged from the lobe in the ovary on the right side. (Right side of worm).

Fig. 30. Shows the oviduct, **od**, leading out of the receptaculum ovorum. In the region of its left end it is joined by the seminal receptacle. (Right side of worm).

PLATE VI.

Fig. 31. A diagrammatic drawing reconstructed from camera lucida drawings of sections. It shows the relation of the organs. This same condition is repeated in the opposite side of the proglottid. The uterus pouches are not shown.

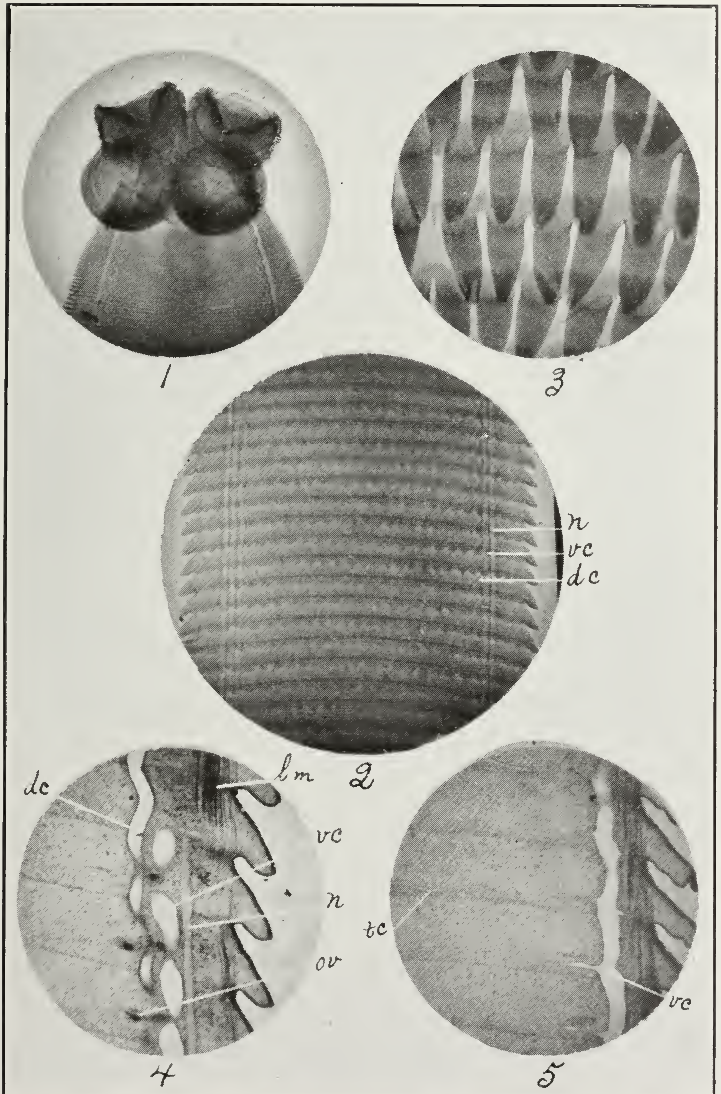

PLATE I.

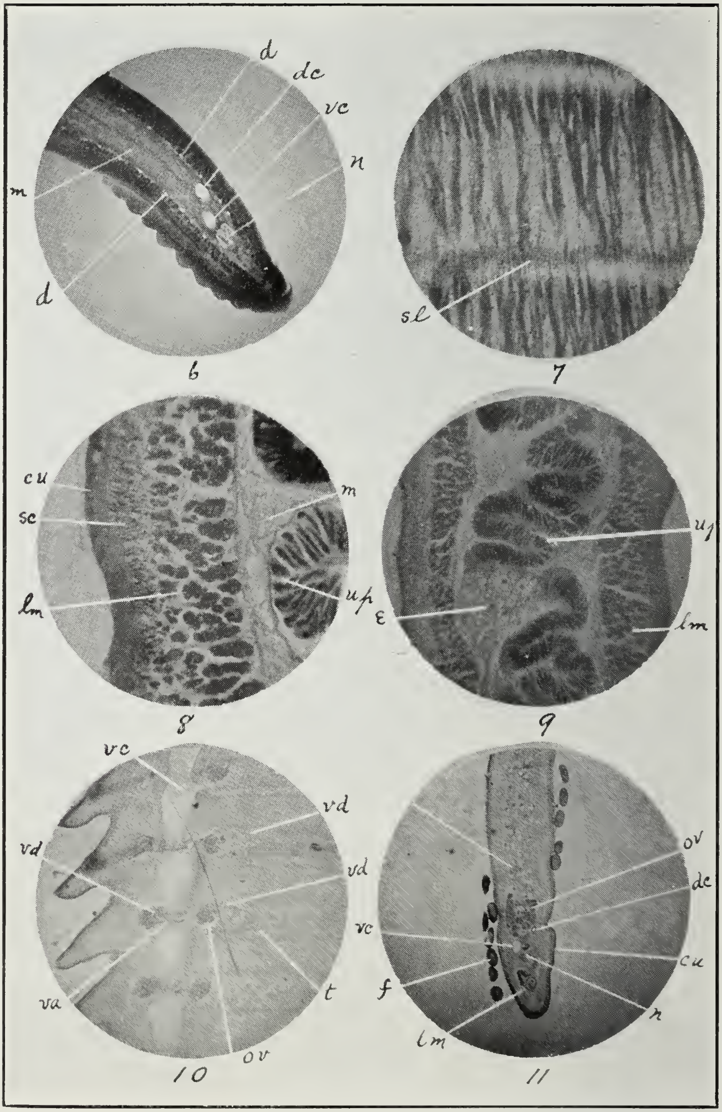
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PLATE II.

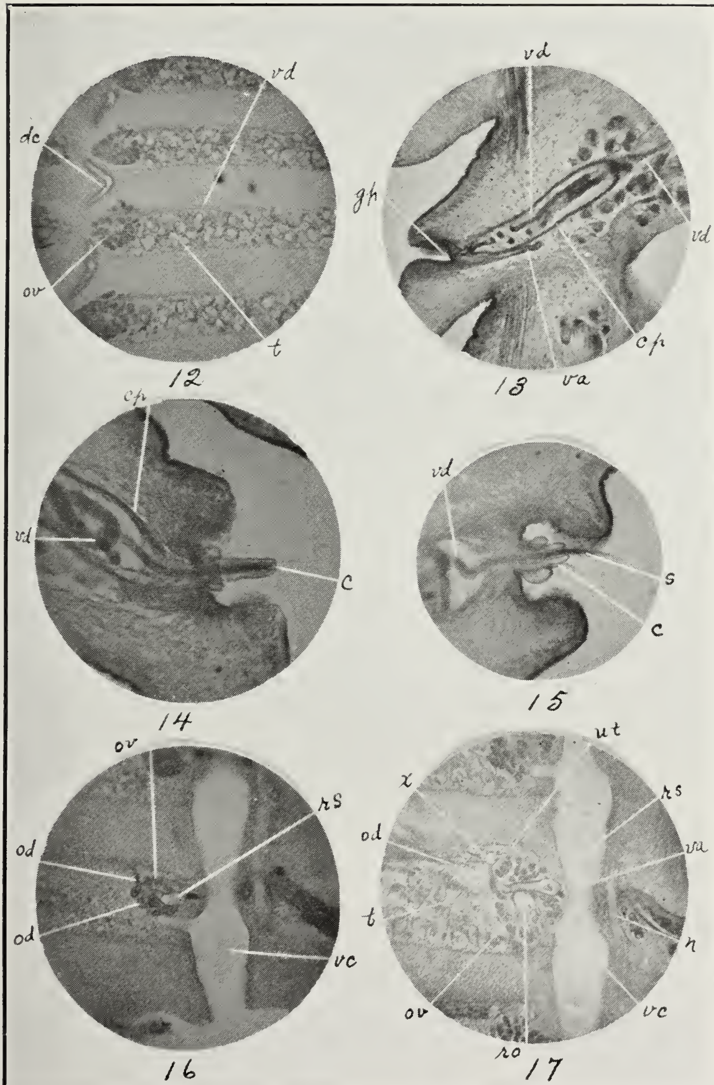
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PLATE III.

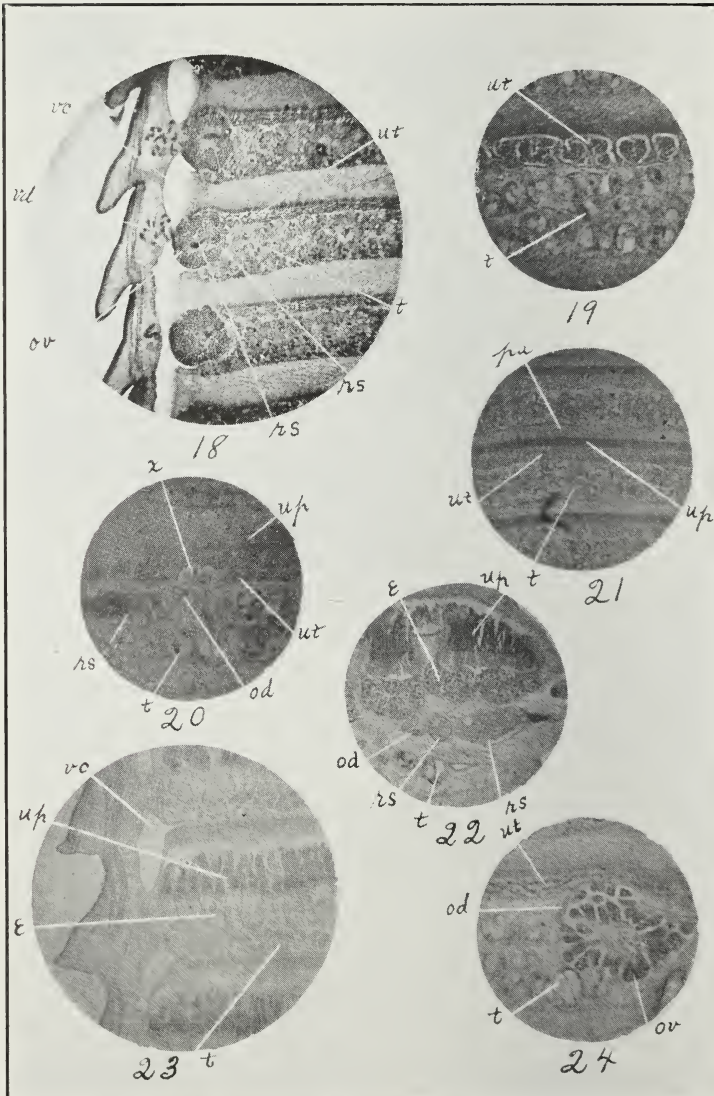
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PLATE IV.

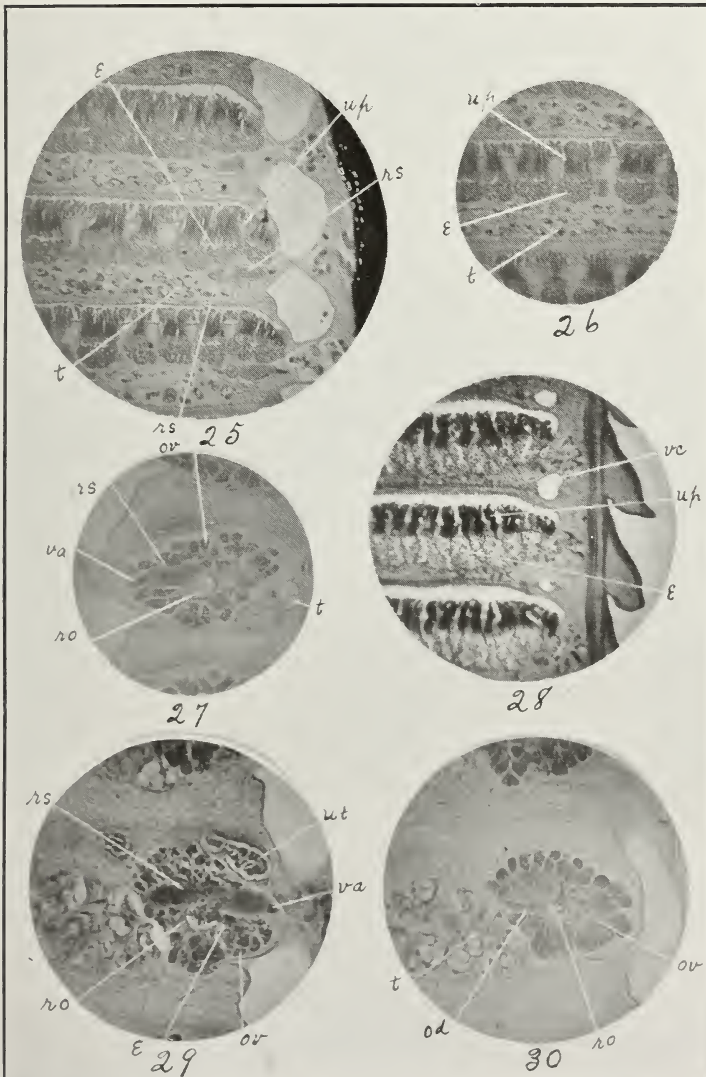

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PLATE V.

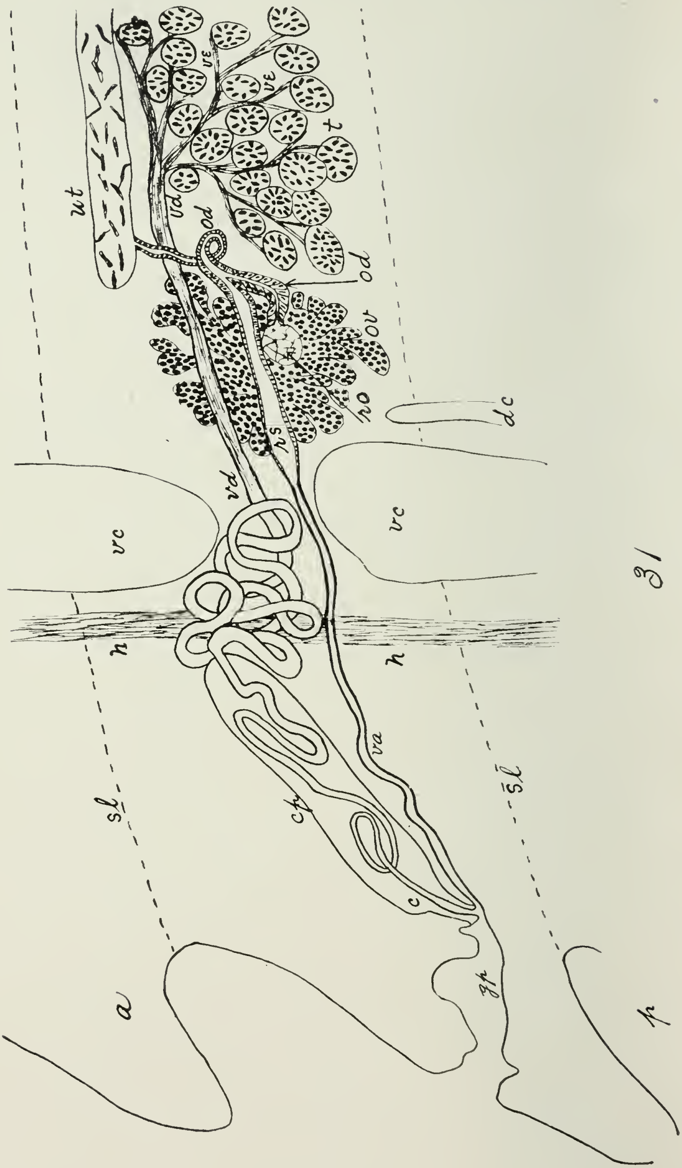

PLATE VI.

UNIVERSITY OF WYOMING

AGRICULTURAL EXPERIMENT STATION

LARAMIE, WYOMING

BULLETIN NO. 103

I. Corn vs. Barley in Lamb Rations
II. Methods of Feeding Barley to Lambs

A. D. FAVILLE, Animal Husbandman.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyoming.

CONCLUSIONS.

When fed to fattening lambs corn gave somewhat better returns than did barley. Pages 4 and 5.

Whole dry barley proved fully as satisfactory in lamb fattening rations as did soaked barley, cracked barley or barley meal. Pages 6 and 7.

Introduction

Henry states that "sheep worth feeding can always grind their own grain." Under eastern condition this statement doubtless holds true, but does it apply with equal force where hard western grains are used? The experiment outlined in the following pages was undertaken with the idea of throwing some light on this question, while at the same time the additional data was gathered as to the relative feeding value of corn and barley.

OUTLINE OF THE EXPERIMENT.

The lambs to be used in this experiment were secured in the fall of 1912 from a flock near Laramie. They were a small, unattractive looking bunch in which Rambouillet blood predominated. Most of them were wether lambs that had been castrated when it was found that they would make inferior rams; and, while they appeared to be rather indifferent feeders, subsequent developments showed them to be a thrifty lot. The lambs were dipped after being taken from the range and all were given similar rations for several weeks prior to the opening of the experiment proper.

Mr. James Wilson, one of the Senior Agricultural students, did most of the morning and evening feeding.

The test was begun November 26th and continued for 110 days. Details as to the weight and number of lambs in each lot and the feeds used are shown in Table A.

TABLE A—*Divisions, Weights and Feeds.*

Lot.	No. in Lot	Avg. Wt. Per Head.	Feed Used.	
		Lbs.	Roughage.	Grain.
I	24	43.1	Alfalfa Hay	Whole Corn
II	24	46.4	Alfalfa Hay	Dry Whole Barley
III	24	44.2	Alfalfa Hay	Soaked Whole Barley
IV	24	43.8	Alfalfa Hay	Cracked Barley
V	24	43.1	Alfalfa Hay	Barley Meal

The lambs though light were in a condition to make rapid gains when given the opportunity.

Second cutting alfalfa hay, exceptionally fine in quality, was fed. This hay was grown near Laramie and was without doubt the best used at the Station for some years.

The barley used (Scotch) was also grown near Laramie and was about average in quality. Soaked barley was prepared by weighing out the amount required for a feed, after which it was soaked in slightly warmed water for 12 hours and allowed to drain suspended in a gunny sack for another 12 hours. Cracked barley was barley very coarsely ground, while in barley meal the barley was made as fine as possible.

Corn was shipped in from the east.

Good shelter and an exercising yard was provided for each lot.

One lamb in Lot III died during the course of the experiment. His place was immediately filled by another animal of the same type and breeding, weighing practically the same as the dead lamb. No readjustment of figures was made because of this loss.

The same amounts of grain were fed each lot and there was almost no difference in the quantity of hay eaten per pen.

RATION RESULTS.

Lots I and II furnish a comparison of corn and barley while Lots II, III, IV and V bring out the value

of different methods of feeding barley. No attempt has been made to compare these lots separately in the following tables.

Table B gives a condensed summary of the weights and gains of each lot of lambs.

TABLE B—*Average Weights and Gains Per Lamb.*

Lot.	Wt. at Beginning Lbs.	Wt. at Close Lbs.	Total Gain Lbs.	Daily Gain Lbs.
I Corn	43.1	82.8	39.7	.36
II Barley	46.4	83.3	36.9	.34
III Soaked Barley	44.2	80.3	36.1	.33
IV Cracked Barley	43.8	79.5	35.7	.32
V Barley Meal	43.1	79.3	36.2	.33

As will be seen at once, gains were uniformly good. Corn gave slightly the best results while the whole barley gave somewhat greater gains than barley fed in any other way.

The lambs at the close of the experiment, though not extremely fat, were in good killing condition and were readily taken by the local markets.

TABLE C—*Average Feed Consumed Per Lamb* (*110*) *Days*

Lot.	Waste Hay Per Lot, Lbs.	Average Feed Eaten Per Head	
		Alfalfa, Lbs.	Grain, Lbs.
I Corn	75	296	79
II Barley	90	295	79
III Soaked Barley	78	296	79
IV Cracked Barley	70	296	79
V Barley Meal	85	294	79

There was almost no difference in the total amount of feed eaten by the lambs in the different lots. The average daily ration per lamb was as follows:

Alfalfa Hay ....2.70 pounds
Grain .... .72 pounds

The average weight of the lambs taken at the middle of the trial was approximately 62 pounds. If feed requirements look small it must not be forgotten that the lambs were small.

The grain ration was increased from .4 of a pound per head at the beginning of the trial to 1 pound during the sixth week and then dropped back to ¾ of a pound during the last weeks of the experiment. Apparently the lambs were forced too rapidly, necessitating a cutting down in the daily allowance.

As a rule, the lambs receiving whole dry barley seemed to relish their grain better than did those receiving barley in any other form.

Table D, giving the feed requirements for 100 pounds gain contains some interesting figures:

TABLE *D—Feed for* 100 *pounds Gain.*

Lot.		Alfalfa Lbs.	Grain Lbs
I	Whole Corn	746.	199.
II	Whole Barley	799.	214.
III	Soaked Barley	820.	219.
IV	Cracked Barley	829	221
V	Barley Meal	812.	218.

Whole corn effected a saving of 15 pounds of grain and 53 pounds of hay when compared with whole barley. In other words, it required 15 pounds or seven per cent less grain and 53 pounds or six and one-half per cent less alfalfa for 100 pounds gain when corn replaced barley in a ration.

Feed requirements for all of the barley lots were remarkably uniform. Dry whole barley gave slightly the best returns, hence it is safe to assume from results obtained in the foregoing trial that soaking, cracking, or grinding western barley does not increase its value in lamb rations.

Grain requirements for 100 pounds gain were unusually low in the experiment, due probably to two im-

portant factors. First, the lambs were in condition to make rapid and economical gains. Second, the alfalfa hay used was exceptionally fine in quality.

TABLE E—*Composition of Feeds.*
(Analysis by F. E. Hepner.)

FEED.	Percentage Composition, Airdry Substance.					
	Water.	Ash.	Crude Protein.	Crude Fiber.	Nitrogen free Extract.	Extract Ether
Alfalfa	6.39	9.30	19.17*	24.84	38.63	1.67
Corn (Mostly Yellow Dent)	10.88	1.39	9.85	1.76	72.01	4.11
Barley	10.02	2.69	10.63	3.53	70.95	2.18

*This alfalfa is richer in crude protein than any other sample of alfalfa analyzed here.

UNIVERSITY OF WYOMING

AGRICULTURAL EXPERIMENT STATION

LARAMIE, WYOMING

BULLETIN NO. 104

Oats and Peas for Ensilage.

FORAGE CROPS

By T. S. Parsons, Agronomist.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyoming.

UNIVERSITY OF WYOMING

Agricultural Experiment Station

LARAMIE

Forage Crops

T. S. PARSONS, Agronomist

INTRODUCTION.

During the past four years some experiments have been conducted at the Experiment Station with a view of gaining some information as to the adaptability of various forage crops to the soils and climate of Wyoming. Numerous inquiries have been received from new settlers and others as to what crops can be grown the first year or two for pasture, hay and forage, to tide them over the time until the land will produce a crop of alfalfa or other hay.

The general subject of forage crops will be treated under three heads as follows:

1st. Leguminous forage crops.

2nd. Gramineous forage crops.

3rd. Miscellaneous forage crops.

DEFINITIONS.

A *forage crop* is any crop the leaves or stems or both of which are used either green or dried for feeding to stock. The green plants may be grazed as in a pasture or they may be cut and fed green as a soiling crop.

Hay is the cured or dry stems and leaves of the

finer grasses and other forage plants.

Fodder is the cured stems and leaves of corn, sorghum, or other coarse plants cut just before maturity and fed without removing the grain.

Field Peas for Forage.

Stover is corn or other fodder from which the grain has been removed.

Certain forage plants, of which corn is the principal one, may be cut green and stored in the silo; the product is then known as *silage* or *ensilage*.

The average altitude of the farming land in Wyoming is 6000 feet. Therefore, it is impossible to grow corn even for forage in many parts of the state. This being the case, it is necessary to grow those crops that will take the place of corn both as dry forage and preserved as silage. For this reason corn will not be discussed in this bulletin.

LEGUMINOUS FORAGE PLANTS.

Under this head may be placed such crops as alfalfa, field peas, vetches and sweet clover. The hardier varieties of beans and the Whip-poor-will cow peas may be

added to this list for the lower altitudes of the state.

Alfalfa is pre-eminently the great forage crop for the semi-arid regions. Every farmer should grow some alfalfa as soon as he can get his land in shape for it. It is difficult, however, to get a stand of alfalfa on new breaking and a full crop is not produced until the second or third year after seeding, so it is necessary for the farmer to grow some other crops as forage until he can have the alfalfa. A fuller discussion of alfalfa will be left for another bulletin.

Field Peas—Field peas are undoubtedly the best of the annual legumes for the higher altitude conditions. They are a cool climate crop and do best where the nights are cool and the days not too warm. A large yield per acre of either green forage or cured hay may be obtained. Peas being nitrogen gatherers also have a beneficial effect on the soil, and probably fit the soil better for

alfalfa than do many other crops. It does not innoculate for alfalfa as the bacteria found on the roots of the pea plants are not of the same species as those found on the alfalfa roots, but there seems to be a physical effect on the soil that is beneficial to the alfalfa.

In the spring of 1910 two small areas were sown to alfalfa. One had been in grain the preceding year and the other in field peas. The soil of each plot was alike and the seeding was done at the same time. The plat that had been in peas gave a perfect stand of alfalfa, while on the plat that had been in grain the preceding year a very poor stand was obtained. The soil on the former plat was in better condition and was compacted more easily after plowing. One of the main factors in successful alfalfa growing is a well-prepared and well-compacted seed bed. The experiment is not of sufficient extent to prove conclusively that the good stand was due

to the peas but indications would seem to point that way. A farmer in the Encampment Valley who sowed a field of alfalfa in the spring of 1913 under directions from this Station reported alfalfa seed sown after peas, April 1st, gave a good cutting of hay, August 10th.

Peas and Oats—Peas being of a trailing or climbing habit of growth, it is generally better to plant them with some grain. Oats, barley, rye or emmer may be used. The straw offers a support for the peas to climb up and they will thus be held up from the ground, make a better growth and the lower leaves will not turn yellow and die as they do when the peas are grown alone. The peas and oats also make a good *ensilage* crop when cut green and put in the silo. All of the peas and oats grown on the Experiment Farm in 1913 were used for this purpose and are now being fed to stock with good results.

Soils—Peas and oats for forage will do very well on nearly all soils. Better soils will of course produce better crops. They have been grown on a variety of soils on the Experiment Farm, from heavy clay to sandy loam. Barnyard manure has proved beneficial to the crop.

Preparation of the Soil—The soil should be thoroughly prepared to make a good seed bed and sowing should be done early, at the higher altitudes as early in the spring as the ground can be worked.

Methods of Sowing—The usual plan has been to sow the oats and peas together, either broadcasting or drilling. It is difficult to set the drill, however, to sow the proper amount of each at the same time, and it has been observed that in many cases when the crop is cut there is a much larger percentage of oats than peas. The oats seem to grow more rapidly and crowd the peas out. Peas will stand deeper planting than oats, therefore, altho no experiments have been carried out along this line, it is suggested that the peas be sown broadcast and disked in to the depth of at least three and one-half inches, or they may be drilled in, and ten days or two weeks later drill in the oats shallower. Thus the peas will have obtained

a good start and will not be so apt to be crowded out by the oats.

Amounts to Sow—The amounts to sow will vary with conditions. Where irrigation is practiced, 60 lbs. of peas and 35 to 40 lbs. of oats per acre should be sown. Under ordinary dry farm conditions where the annual rainfall is from 14 to 18 inches, 25 to 30 lbs. of each should be sown.

Varieties of Peas—The White Canada is the variety most generally grown. The high prices for seed prevailing the last two or three years, however, have made the use of this seed almost prohibitive. The Colorado Stock Peas have been used at the Station the last two years and have been found fully as satisfactory as the Canadian variety and have the advantage of being much cheaper.

The Colorado Stock Pea is a hybrid which originated in the San Louis Valley of Colorado. It probably came from the Golden Vine intermingling with the Native or Mexican peas. It grows tall and has purple blossoms. It is fully as hardy as the Canadian pea and as good a yielder.

Three new varieties of field peas were imported by the Department of Agriculture and sufficient amounts of each were sent to this Station for trial in 1913. The three varieties, known as Bangalia, Amraoti and Kaiser, made fair yields of forage but no better than the Canadian or the Colorado Stock Peas. They need to be tested further as regards their value for either seed or forage.

Peas with Other Grains—Peas may be sown with fairly good results with other grains, such as barley, rye and emmer, but the combination with oats usually gives the best results, altho a heavy yield of peas and emmer was obtained on the Experiment Farm in 1912. (See Table). Barley is very good for late sowing as it grows more rapidly and does better in hot weather than oats.

Vetches—The vetches generally grown are of two kinds, spring vetch (*Vicia sativa*) and the hairy or winter

vetch (*Vicia villosa*) The latter is the only one that is recommended for Wyoming conditions. It may be sown in the fall with rye and under ordinary conditions will produce considerable forage. It has been sown with fall rye at the Experiment Station but winter killed badly. At the lower altitudes of the state it should be a good crop for fall sowing with rye, or wheat. It is quite hardy and alkali resistant. germinating well on soils too alkaline for most legumes. The plat on which rye and vetch was sown in the fall of 1911 on the Experiment Farm was quite alkaline, in fact so alkaline that field

Swedish Select Oats for Forage.

peas sown on it the previous year did not germinate. The vetch germinated readily and grew well in the fall. The small yield was due to winter-killing.

Rye and Vetch—On May 9, 1911, a one-half acre plat was sown to one bushel of spring rye and 12 lbs. of spring vetch (*Vicia sativa*). The rye made an excellent growth but the vetch did not come well so it was decided to let the rye ripen for seed. The plat produced 343 pounds of grain, or at the rate of 14.9 bushels per acre. If the plat had been cut green for forage it probably

would have produced about one ton of rye hay.

Another half-acre plat was sown on the same date to one bushel of oats and twelve pounds of vetch. This made a good growth and was given but one irrigation of 1.05 feet of water during the season, and two cuttings of forage were made, the first on July 31st of 1810 lbs. of cured hay and the second on September 5th of 880 lbs. of cured hay, a total for the plat of 2690 lbs., or a yield of cured hay of 2.19 tons per acre.

Oats and vetch made a good forage, probably as high in feeding value as oats and peas, but the oats and peas will give a larger yield as vetch does not germinate as well as the peas, altho a heavier sowing of the vetch would probably be better.

In 1912, one acre was devoted to forage crops for the purpose of comparing vetch and oats, peas and oats, and peas and barley. One-quarter acre was devoted to each crop. Thru a misunderstanding on the part of the man seeding, peas and emmer were combined instead of peas and barley.

All of the plats were sown on May 20th. The plats received but one irrigation and all of the plats were cut on August 16th. The average height of the grain was forty inches and just in the dough stage when cut. Yields for each quarter-acre were as follows:

Vetch and oats, 980 lbs.

Peas and emmer, 1040 lbs.

Peas and oats, 600 lbs.

Hanna barley, 770 lbs.

The barley alone made a good yield of hay. This variety is a two-rowed species and is very leafy, being probably the best barley for forage. Had it been combined with peas the yield would probably have been heavier.

The emmer and peas made the best yield in the trial and it would seem that this combination would be a good

one for forage. The yields given in each case are of cured hay.

Sweet Clover—The sweet clovers are biennial plants belonging to the clover family. They do not produce flowers or seed until the second year, when they mature seed and die. There are two species, the white and the yellow. The white is most extensively grown and is the best forage. On account of its scarcity the seed is more expensive than the yellow. For this reason the yellow is often grown instead of the white. During the past three years the white sweet clover has been grown under various conditions at this Station with good success, and stock have eaten it readily. Small amounts of the yellow have been grown but it has not produced as much forage as the white. At the east side of the Agronomy Farm is an area of land consisting of about four acres which receives seepage from the land above and consequently is too alkaline for the growing of grain crops. According to records, this area was sown to white sweet clover in 1908. A fair crop was harvested in 1909 and in 1910, after the writer took charge, one and one-half tons of cured hay was produced on the area from one cutting. A heavy frost on August 24th prevented a second cutting and no seed was produced. In the spring of 1911 no growth of sweet clover appeared, according to the nature of the biennial. This does away with the theory sometimes advanced that sweet clover will spread badly when once sown and becomes a bad weed pest. If cut before it goes to seed there is no danger of its spreading, and it makes an excellent quality of hay if cut before the stems become woody. These plats have been kept in sweet clover (new sowings being made every two years), as no other plants other than some of the native grasses will grow on these plats which are heavy clay and strongly alkaline. The plats are low and receive some seepage, consequently do not require heavy irrigation. The land received .274 feet of irrigation water and .362 feet of rainfall, or a total of .636 feet of water.

Sweet clover will also do well on the dry farm. On

May 4, 1911, an area of two acres was sown to sweet clover on the Holliday farm in the dry farm experiments then being carried on. The crop was sown at the rate of 10 lbs. per acre. The plants made considerable growth that year but not sufficient for cutting. One acre was badly covered by blowing soil; the other acre, however, produced 3700 pounds of hay the following year. Sweet clover can be grown successfully without irrigation on lands too dry for alfalfa.

GRAMINEOUS FORAGE CROPS.

This group includes all of the grasses and grains

Brome Grass (Brosmus Inermis).

grown and cut for forage, whether fed green or cured for hay. Some of the grains have been discussed with the legumes, so no further discussion is needed here except to say that they are better grown in combination with legumes, especially field peas, as in this way larger yields are obtained and they also make a better balanced ration. Oats, barley, and rye are the grain plants most commonly grown for forage. Experiments with various grasses and grass mixtures are being carried on to determine those of most value for the pastures and hay.

Full discussion of these will be given in a future bulletin. It will suffice to say here that Brome Grass (*Bromus Inermis*) has been found to be an excellent pasture grass, forming a very thick sod after two or three years. It starts growth very early in the spring and remains green late in the fall. It is better adapted for pasture than it is for hay, altho it will produce a good quantity of hay when well cared for. In 1913, a quarter-acre plat that had been sown in 1911 produced 1000 lbs. of cured hay. This is at the rate of two tons per acre.

MISCELLANEOUS FORAGE CROPS.

This group includes such crops as millets, sorghums, Kaffir corns, etc., which, altho they belong to the Gramineae, make rather a group of themselves, and can be grown in various parts of the state. On account of conditions at this altitude, not much has been done along the line of experimentation with these crops. The Manitoba or Hog Millet and the Siberian Millet do fairly well but are quite easily injured by frosts and do not make heavy yields. The Kirsk Millet, now being distributed by the Government, promises fairly well. It is being tried both under irrigation and dry farming conditions. Reports from sections of the state at altitudes not above five thousand feet indicate that most of the millets, sorghums and kaffir corns can be successfully grown for forage and in some instances corn, especially the flint varieties. Early Amber Sorghum, Yellow Milo Maize and Kirsk Millet are recommended as the hardiest crops of this group.

Rape has proved a good forage crop at this Station. It is easy to grow and produces a large yield of succulent forage, adapted to hog or sheep feeding. It is not cut but pastured in the field. Sheep and hogs like it and do well when fed on it.

Many inquiries have come to this office concerning the new forage plant, Feterita. This is a warm climate plant belonging with the sorghums and it is very doubtful if it can be grown successfully anywhere in Wyoming.

Name of Crop	Year	Area	Date Sown	Date Harvested	Yield in lbs.	Tons. per A
Field Peas	1910	2 1-2	May 10	Sept. 10	10,000	2.
Amber Cane	"	1	May 20	No Crop	Frosts	
Corn, 4 varieties	"	2	May 15	" "	"	
Oats	"	1 1-2	Apr. 10	Aug. 25	2,210	2.21
Sweet Clover	"	1	1909	Aug. 24	3,000	1.5
Rape	"	1-2	Apr. 15	Not Cut	10,000	10. est.
1. Oats and Peas	1911	1-2	May 24	Sept. 4	,280	.28
Oats and Vetch	"	1-2	May 9	2 cutsJl 1-Sep5	2690	2.69
2. Sweet Clover	"	1	1909	July 29	2,000	1.
Corn, 2 varieties	"	1-4	May 20	No Crop	Frosts	.5
3. Siberian Millet	"	1-2	May 24	Sept. 4	,500	.5
Manitoba Millet						
Vetch and Oats	1912	1-4	May 20	Aug. 16	,980	1.96
Peas and Emmer	"	1-4	May 20	Aug. 16	1,040	2.08
Peas and Oats	"	1-4	May 20	Aug. 16	,600	1.2
Barley	"	1-4	May 20	Aug. 16	,770	1.54
Corn, 15 varieties	"	1-2	May 20	No Orop	Frosts	
4. Sweet Clover, irrigated	"	1	1910	Aug. 25	2,000	est 1ton
	"		May 4			
Sweet Clover, dry farm	"	1	1911	Aug. 20	3,700	1.85
	"					
Millets	"	1-	May 7	No Crop	Frosts	
5. Peas and Barley	1913	1	May 4	Aug. 27	3,400	1.7
6. Wheet	"	1-2	May 4	Aug. 21	1,950	1.95
Barley	"	1	May 7	Aug. 21	9,445	4.22
Oats and Peas	"	1 1-2	May 3	Aug. 22	11,267	3.75
Oats and Peas	"	3-4		Aug. 17	8,915	5.95
Corn	"	1-2	1911	No Crop	Frosts	
Brome Grass	"	1-4		July 11	,920	1.80
Field Peas, ensilage	1914	3-4	Apr. 25	Aug. 7	7,805	5.2
Alfalfa and Timothy, hay 2 cut'gs	"	1-5	1911		1.710	4.225
Sweet Clover, hay	"	1	1911	July 1	3,300	1.15
Field Peas, cured hay	"	3	Apr.28	Aug. 4	17,255	2.32
Oats and Peas, cured hay	"	3	Apr.28	Aug. 5	21,665	3.22

LIST OF FORAGE CROPS.

NOTES ON THE TABLES:

1. Sown on plat that was very weedy the preceding year. The crop was largely weeds. This accounts for the low yields. The oats and peas, however,, cleaned up the plat and put it in excellent shape for the next year' scrop.

2. This was the second year for the sweet clover and the crop was not as heavy as the first year after seeding.

3. The millets made some growth but the plat was very weedy. A paying crop was not obtained.

4. This was the third year for the sweet clover. It self-seeded to some extent from the preceding year. It was cut before seeding this year and the plants had disappeared entirely the next year.

5. This and the four following were cut and hauled to the silo in the green stage. Destruction by gophers caused the small yield.

6. This plat was eaten by gophers which lowered the yield. It made good silage.

Corn, sorghum, and milo maize have never made a crop.

CONCLUSIONS:

Peas and oats give the best results under all conditions for either hay or ensilage.

Barley, rye, emmer or oats may be sown to advantage with peas. For late sowing, barley is best. Six to eight tons of peas and oats in the green state can be raised on an acre under the best conditions. Four to five tons per acre make it a paying crop.

At altitude below 5000 feet corn can be raised successfully for silage or fodder at least.

White sweet clover makes a good crop where alfalfa cannot be grown. Stock eat it readily. It will not become a pest if not allowed to go to seed.

Soya beans and cow peas can probably be grown successfully in the lower altitudes of the state.

The vetch may be substituted for peas with oats under some conditions but peas are usually better yielders.

The winter vetch (*Vicia villosa*) may be sown with winter rye on the dry farm to good advantage.

All forage crops do better on well-prepared soil. Legumes used as forage crops perform two offices. They produce a large amount of forage and are nitrogen gatherers which enrich the soil.

Other station reports state that oats and peas are second in the value of corn for the production of forage. One bushel of peas and one to one-half bushels of oats should be sown on an acre.

Some provision for forage crops should be made on every farm to provide against failure of the regular hay crop.

As a heavy growth of plants is desired in forage crops, where irrigation water can be used if conditions are favorable than with grain crops. The crop should never be allowed to suffer for the want of water. Two or three irrigations during the growing season are usually sufficient. There is little danger, however, of giving a forage crop too much water.

UNIVERSITY OF WYOMING

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The Eradication of the Sheep Tick

By L. D. SWINGLE

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyoming.

UNIVERSITY OF WYOMING

Agricultural Experiment Station

LARAMIE

Errata:

BUL. 105, ERADICATION OF THE SHEEP-TICK.

Page 29, line 1, "objects" should read "object."

Page 33, line 27, "quite" should read "quiet."

Page 35, line 10, "immerser" should be "immersed."

Page 36, line 8, "Coopers's" should be "Cooper's."

Page 42, line 14, should read: "before any will have laid pupae."

Page 42, line 17, "dippins" should be "dippings."

Page 46, line 2, under (d), "wark" should be "work."

The Eradication of the Sheep-Tick

(*By LEROY D. SWINGLE.*)

In a recent bulletin (No. 99) the results of my work on the life-history of the sheep-tick were published. Those results, together with more recent data obtained regarding the action of sheep dips upon the ticks, serve as a basis for determining efficient methods of eradicating this pest.

It is common knowledge that all the ticks on a flock of sheep can be destroyed by any one of several sheep dips. Every one also knows that after a few months the sheep are found to be reinfested. The owner often attributes this to the sheep's picking up stray ticks from bedding or vegetation of the pasture. This error is doubtless due to the fact that he does not distinguish between the sheep-tick and the *true* tick, which may live for a long time off its host. The sheep-tick will live but a short time, generally but three or four days, off the sheep and is not prone to leave its host. The true explanation of reinfestation lies in the fact that none of the sheep dips are effective in destroying all of the pupae (eggs) present in the wool at the time of the dipping. And, therefore, in a few days after dipping, young ticks hatch out and infect the whole flock.

If a dip were available that would absolutely kill not only all of the ticks but all the pupae without injury to the sheep or wool, the problem of complete eradication of the sheep-tick would be easily solved. Yet, though such a dip is doubtless not to be had, it is still perfectly

possible to eradicate the tick not merely from a few flocks of sheep but as well from the whole state or even the United States.

In discussing the eradication of the sheep-tick the following important questions must be considered:

1. What is the effect of sheep dips upon the pupae (eggs)?

2. Does dipping of the pupae modify their incubation period?

3. What is the effect of various dips upon the tick?

4. Which are the best dips to use?

5. How many dippings are necessary, and when should they be made, in order to eradicate the tick?

In solving these problems it was not expedient to try all of the sheep dips that are on the market. Some of the dips having a good reputation were used. There may be other dips as good or perhaps better. But the main object was to find a dip that would certainly kill the ticks and accomplish this result without much injury to the sheep and the wool, and without excessive cost and inconvenience.

In the experiments to determine the effect of dips upon the pupae and ticks, the element of time was considered important.

In dipping for sheep-ticks only, it was considered impractical to leave the sheep in the bath more than one minute unless no dip could be found that would be effective in that time. However, in case a very long vat is used the sheep would naturally remain in the bath more than one minute. This would also be true if the sheep were being dipped not only for ticks but also for scabies because in dipping for the latter it is the practice to leave the sheep in the bath longer in order to soak up the scabs. Since in these experiments only the sheep-tick was being considered, the pupae and ticks were generally immersed only one minute.

In the first experiments on the pupae the only objects was to determine whether pupae would hatch after being treated with sheep-dips. The percentage of pupae killed was considered in some of the later experiments. The first four experiments were carried out on lambs, and the dips used were Cooper's powder, Zenoleum, crude carbolic acid and the official lime and sulphur dip. In every case pupae hatched readily. In the case of the lime and sulphur dip even the ticks themselves were not killed.

Some laboratory tests were then made with several other dips. In each case several pupae were placed in the center of a handful of wool, which was then immersed in the dip. The wool was removed after one minute and allowed to drain and dry, much as in the case of actual dipping. The following dips were tried: Chloroleum 1:63, Carboleum 1:100, Cooper's Fluid Dip 1:150, Kreso 1:75, Chloro-naptholeum 1:50, Zenoleum 1:50, and kerosene emulsion, the quantity of kerosene being 25 per cent. Many pupae from each group, except that dipped in kerosene, hatched.

It is therefore seen that none of these dips, except kerosene, will kill all the pupae. But kerosene in 5 per cent strength will not kill all of them and in a higher percentage it is impractical. Even Zenoleum in 2 per cent. strength will not kill all of the pupae.

In some other laboratory tests the relative killing action of several dips on pupae was considered. At first no controls were kept but it soon became apparent that they were necessary in order to give an accurate estimate of the killing power. From these experiments the relative killing action may be indicated by the following tabulation in which the strongest is placed first and the weakest last: *

**"Black Leaf 40" was also used in these tests, the results being represented by 11.1 units. It is claimed that Black Leaf is slower in its action and hence the directions demand that the sheep be kept in the bath two minutes. In this test the pupae were immerser only one minute.

Kreso 1:75	48.9
Sanitary Fluid (Betz) 1:200	48.1
Zenoleum 1:100	45.8
Crude Carbolic Acid (drug store sample) 1:200	41.4
Crude Carbolic Acid (drug store sample) 1:800 and Kerosene 1:20 plus 1 per cent. soft soap	40.3
Zenoleum 1:100	28.0
Minor's Fluid 1:80	28.0
Chloroleum 1:63	23.2
Sanitary Fluid (Betz) 1:100 plus ½ per cent. hard soap	14.0
Crude Carbolic Acid (drug store sample) 1:400 plus ⅓ per cent hard soap	12.9

It will be seen that there are variations even in the action of the same dip and hence not much reliance can be placed upon these results except when they are confirmed by other experiments.

There are evidently some unknown factors involved.* In every instance but one the pupae of the controls began to hatch before those that had been dipped. This probably is due largely to the cooling action of the wet wool rather than to the possible fact that the pupae which were about ready to hatch were killed by the dips. Another important fact is that the controls continued in every case to hatch for several days after all hatching had ceased among the groups that had been dipped. This means that all of the youngest pupae were killed by the dips, and this conclusion is supported by other data. These experiments indicate that more than one dipping must be made if the tick is to be eradicated.

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*Some later experiments which are not reported in this paper indicate that there are certain physical or chemico-physical factors involved in the action of dips upon ticks. Further experimental work, which is being prosecuted along these lines, must be completed before the facts can be presented.

In using the life-history as a basis for determining when the last dipping should be made in order to eradicate the tick, it is necessary to know whether the first dipping lengthens the incubation period of the pupae that are not killed. Since the dips will not kill all of the pupae, it is necessary to place the last dipping after every pupa has hatched. In the summer time the normal incubation period may reach 23 days, so that the last dipping could not be made till 23 days had elapsed after the first dipping. But, if the first dipping should have such effect upon the pupae as to delay their hatching, it would be necessary to delay the second dipping proportionately, unless it can be shown that the last dipping, falling 23 days after the first dipping, will kill those pupae that have not yet hatched. Experiments show that the last dipping will not kill such pupae. Therefore, it is necessary to know whether the incubation period of pupae is prolonged by the first dipping.

Several experiments were made to determine this point. The method employed was to collect several female ticks which were ready to lay their pupae and confine them on a sheep in an area of wool which had been freed from pupae. The next day, the pupae which they had laid during the night were collected and divided into two groups. One group was dipped in Zenoleum 1:100 and the other kept as a control. Both groups were placed under exactly the same conditions either on a sheep or in the laboratory. It was found that, if the pupae were dipped before they were about four days old they were kiled, instead of the incubation period being prolonged. But when dipping was delayed four days, only part of the pupae were killed. In one of the experiments there was indication that the period might be prolonged four days. But since the pupae that are less than four days old are killed by the dip, a prolongation to the extent of four days of the incubation period of pupae over four days old does not prevent their hatching within 23 days after the first dipping, altho their whole incubation period might reach 27 days. And so we conclude that the possibility of a prolongation of

the incubation period by the first dipping need not be considered in determining when the last dipping should be made.

The third question for consideration is:

"What is the effect of the various dippings upon the ticks?"

In testing the action of dips upon ticks it was necessary to divide the dips into two groups, namely, those whose action is immediate because they are absorbed, and those whose action is more or less remote, owing to the fact that they are but slightly absorbed, their killing power being due largely to their being ingested. The coal tar and cresol dips and "Black Leaf 40" belong to the first group and Cooper's Powder Dip to the second. The first group admit of laboratory tests, while the second group had to be tested by actual dipping experiments.

It is more difficult to determine the relative effects of different dips upon the ticks than one would anticipate. The ticks may be stupefied so that they are apparently dead. But if they are removed from contact with the dip they may revive. The matter of time is an important factor to be considered in determining the killing power of a dip. Generally it would not appear practical in dipping a large flock of sheep to leave them in the vat over a minute, except, as stated before, when the vat is very long so that the movement of the sheep needs not be retarded, or when the sheep are being dipped for scab also. And so in testing the dips the ticks were immersed only one minute. It is true that according to directions with some dips the sheep should be left in as long as two minutes. But generally in comparing such dips I left the ticks in only one minute, the same as with other dips. It might also be held that it would not be fair to compare the dips without using them in uniform strength even though directions with one dip may demand that it be used in solution five times as strong as

another. But this is an entirely different question. For example, if "Black Leaf 40" were to be used in a dilution of 1:50 as Kreso is used, it would probably kill the sheep and would cost about twenty times as much. It would without question be stronger than Kreso and would also be much stronger than would be necessary. We see, therefore, that there are other factors such as the effect upon the sheep and the cost of the dip that are involved when the strength of the dip is considered.

At first it appeared reasonable that the killing power and hence the relative value of a dip could be determined by holding ticks under the dip and noting the time required for all movements to cease. It is plain that in the case of ticks external movement is the only indication of life, or at least the only practical indication that could be used in these experiments. Yet this sign is not entirely satisfactory inasmuch as all external movements may cease for a long period while the tick is under the influence of the drug, and then return when the drug is removed, indicating, of course, that the tick was not quite dead. Still in the absence of any more practical and fundamental sign of life, this one had to be used. It was found best not to depend upon the cessation of voluntary movements, but to determine when artificial stimuli would no longer evoke movements. This was necessary because ticks may become quite spontaneously unless irritated.

The dips used in the laboratory tests on ticks were (1) Zenoleum; (2) Chloroleum; (3) Chloro-Naptholeum; (4) Kreso; (5) Minor's Fluid; (6) Sanitary Fluid *; (7) Pyxol **; (8) Crude Carbolic Acid; (9) Carbolic Acid; (10) B. & C. Cresol; (11) Cooper's Fluid Dip (Cresol); (12) "Black Leaf 40." The first eight appear to be very similar coal-tar compounds and when mixed with water make a white, milky fluid. Crude car-

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*Sanitary Fluid may be obtained from the F. S. Betz Co., Hammond, Indiana.

**Pyxol is put out by the Barrett Manufacturing Co., 17 Battery Place, New York City.

bolic acid will not mix with water without the addition of soap and if the water is hard, a softener. Tests show that the first five dips when used according to directions are very effective killers of sheep-ticks. Betz's Sanitary Fluid and Pyxol have not been advertised or used as sheep-dips and so no directions regarding their use as such accompany them. Experiments indicate that Sanitary Fluid in the proportion of 1:100 and Pyxol 1:200 are very effective. There is evidence that Pyxol is much more poisonous to sheep-ticks than carbolic acid, and it need not be used in greater strength than 1:200. The best crude carbolic acid, which was tested, is the Denver Fire Clay Company's (50-60 per cent. quality containing napthalene). This, used in the proportion of 1:200, with ½ per cent. soap and ⅛ per cent. sal soda, is a very effective dip. I regard the action of B. & C. Cresol and Cooper's Fluid (Cresol), when used in the proportions called for by the directions, as less certain than some of the coal tar compounds. They were not tried in actual dipping experiments. They may possibly kill all the ticks, but I believe with less margin to spare than is the case with the best coal-tar dips when used in the strength indicated by their directions. "Black Leaf 40" proved inferior to the coal-tar dips in the laboratory tests, even when used according to directions, which call for the conditions that the ticks remain in the bath 2 minutes, and the bath be of 100 to 105 degrees. Similar results were obtained by two actual dippings, but in one of the tests the dip was used cold and the sheep were not left in it longer than in the case of Zenolum (probably one minute).

It is worth while to mention in detail some of the tests that were made in the laboratory. I will select Pyxol and Cooper's Fluid Dip. According to directions the latter is to be used in the strength of 1:200. At first Pyxol was used in the ratio of 1:150. Ticks were placed in the center of a handful of wool which was immersed in the Pyxol bath for one minute. It was then removed and allowed to drain for five minutes. The ticks were left undisturbed in the wet wool. These conditions simulated the conditions that prevail in actual dipping.

Eighteen minutes after the wool was immersed the ticks were examined. Only one showed voluntary movements. Twleve minutes later none showed voluntary movements and a minute later only one showed movements under irritation and that almost imperceptible. Another group of ticks were similarly treated with Cooper's Fluid 1:200. While the wool was draining some of the ticks crawled out on the surface of the wool. They were placed back in the center. Eighteen minutes after the wool was immerser it was opened and the ticks were examined. Four of them showed voluntary movements. Fifteen minutes later one was very irritable and five others showed slight response under stimulation. These facts indicate that Cooper's Fluid 1:200 is inferior to Pyxol 1:150.

A comparison exactly like the above was made between Pyxol 1:200 and Cooper's Fluid. In the case of Pyxol, fifteen minutes after dipping began no voluntary movements were present. Twenty minutes later practially no response could be evoked by stimulation. In the case of Cooper's Fluid, sixteen minutes after dipping began six of the ticks were found crawling in the wool. Nineteen minutes later voluntary movements were still present in several. This indicates that Pyxol 1:200 is superior to Cooper's Fluid 1:200

The above results were confirmed by tests of a different nature. The ticks were divided into groups of ten each. The groups were immersed for varing lengths of time in the dips and then removed to open boxes. In the first experiment one group was immersed for two minutes in Pyxol 1:150, and another for the same time in Cooper's Fluid 1:200. In the former case only one showed voluntary movements 100 minutes after dipping, while in the latter case all were much more lively. Six hours after they were dipped, the first group showed very slight movements under irritation, while the latter group were as lively as if they had not been dipped. Twelve hours later those dipped in Pyxol were all dead, while those dipped in Cooper's Fluid were as lively as ever. A similar comparison was made between Pyxol

1:200 and Cooper's Fluid 1:200. The ticks were dipped for eight minutes in each case. Four hours after dipping there were no movements under irritation in either group. Tweleve hours later those dipped in Cooper's Fluid had revived and become very active, while those from Pyxol were all dead. I will not record the remaining experiments but only add that they confirmed these results, namely, that Pyxol 1:200 is superior to Coopers's Fluid 1:200.

In order to determine the value of Cooper's Powder Dip, which is an insoluble arsenic compound, actual dipping experiments were made. It was found that one dipping with it would come nearer to destroying the ticks than one dipping with Zenoleum. Yet the fact that one female tick and two live pupae were found on one of the lambs four months after the dipping had taken place, would indicate that one dipping cannot be relied upon to absolutely eradicate the ticks. That ticks may be found on the lambs for a month after the dipping is not an indication that the dip is not effective, for the pupae may be hatching for three weeks or more after the dipping and several days may elapse before they eat enough poison to kill them. Sufficient powder remains in the wool to kill most of the ticks, as was shown by the following experiment.

A sheep having wool about two inches long was dipped according to directions in Cooper's Powder and allowed to dry for three days. Then fifty ticks were placed in the wool. The following day most of the ticks were gone. But some of them were still alive and others were found dead in the wool. After about three days no live ticks could be found. Then fifty more live ticks were placed on the sheep. The same conditions were repeated. This sheep was later turned in with infested sheep and remained comparatively free from ticks for some time.

On June 21st, a flock containing 75 sheep and their lambs were dipped according to directions in Cooper's Powder. The sheep had been sheared about a month earlier. On July 29th two or three ticks could readily be

found on a lamb, but none could be found on the sheep. On this date they were dipped again in Cooper's Powder. A month later no ticks could be found. On January 5th, about 6½ months after the first dipping, no ticks were present.

On June 21st, another group containing 17 sheep with long wool and 13 lambs with very short wool were dipped in the same Cooper's Powder mixture that was used in the first dipping of the preceding experiment. Thirty-eight days after the first dipping, this group was dipped again. After dipping the preceding group in Cooper's Powder there remained 250 gallons of dip in the vat. To this were added two gallons of Zenoleum. In this mixture, the group were dipped. Thus, the slow but prolonged action of Cooper's Powder was combined with the rapid killing action of Zenoleum. Frequent examinations during the six subsequent months failed to reveal any ticks.

I have seen large flocks of sheep practically, if not entirely, freed from ticks by a yearly dipping in Cooper's Powder Dip. The shearers testified that they did not find a tick. The conclusion is justifiable that two dippings with this preparation is certain to eradicate the ticks absolutely. There is evidence that one dipping cannot be depended upon to eradicate them. No chances should be risked and so a margin of safety as wide as is practical should be maintained, though a little extra expense may be involved. The expense will never have to be repeated, if the work is done rightly in the first place.

Some actual dipping tests were made with certain other dips. On June 15th, three sheep and five lambs were dipped in Chloroleum 1:80 (the directions call for the proportion 1:75). After the adults were dry they were sheared. Twenty-eight days after the first dipping, although a hasty examination revealed no ticks, we dipped the group in Chloro-naptholeum 1:75. About two months later and again in about six months they were carefully examined, but with negative results.

On June 21st, a group of 27 large wethers, with a half year's growth of wool, were dipped in Zenoleum 1:100. Thirty-one days later, altho no ticks were noticed, they were dipped with Zenoleum 1:100. Six months later they were sheared, but no ticks were found.

A group of thirteen sheep (having one year's growth of wool) and nine lambs were dipped in the fluid that remained after the wethers were dipped. Ticks were present on the lambs twenty-three days later, and so they were dipped again in Zenoleum 1:100. These dippings destroyed the ticks and the group was still clean six months later.

Another group containing 15 sheep (with one year's growth of wool) and 14 lambs, were dipped June 23rd in "Black Leaf 40", strength 1:686. The bath was used cold. Four pounds of sal soda were added to each 100 gallons of water. The sheep and lambs were left in the dip about the same time as was the case with the other dips. On July 1st, ticks were present on the lambs. On the 14th they were present on the sheep and numerous on the lambs. On the 16th, 23 days after the first dipping, the group were dipped again in "Black Leaf 40", 1:686, cold. The lambs were left in much longer this time. On July 22nd ticks were present on the lambs. Another examination was made August 22nd, and the ticks still being present, we dipped the group in Zenoleum 1:100. These three dippings destroyed the ticks and at the last examination, about five months later, no ticks could be found.

We may now consider the next question, "Which is the best dip to use?" Our decision must take in account at least five factors: (1) The killing power. (2) The effect upon the sheep. (3) The effect upon the wool. (4) The cost. (5) The ease with which the dip can be prepared. It is apparent that some of these factors are more important than others, and hence must be given more weight. Of greatest importance is the first. We must select a dip that will certainly kill the ticks, even though it might cost more, require more effort in its

preparation, or even be more injurious to the sheep and wool than another dip that may be better in respect to the last factors but will not kill the ticks. But between two dips that have equal killing power we should choose the one that is best in respect to the less important points.

Since the work on the sheep dips has not been extensive enough to draw sharp comparisons between them, I will merely indicate some of the dips that when used as recommended, will certainly destroy the ticks. They are: Chloroleum, Chloro-naptholeum, Kreso, Zenoleum, Minor's Fluid, Sanitary Fluid (Betz) 1:100, Pyxol 1:200, Crude Carbolic Acid (50-60 per cent. quality, Denver Fire Clay Co.) 1:200 or 1:300, and Cooper's Powder Dip. In the comparisons between "Black Leaf 40" and the other dips, Black Leaf was not generally used according to recommendations. Its effectiveness would undoubtedly be increased by such conditions.

In respect to the effects upon the sheep and wool, and in respect to ease of preparation, there is not much difference between the different coal-tar dips mentioned, except crude carbolic acid which blackens the wool more and is hard to prepare. Therefore, with the exception of crude carbolic acid, the only question to be considered in selecting a dip from this group of coal-tar dips is the cost. From quotations on large quantities of dips, I can give the cost per one hundred gallons of mixture ready for use: Kreso, $1.00 to $1.30; Zenoleum, 90c.; Chloro-naptholeum, $1.00; Chloroleum, 1:75, $1.13; Pyxol, 1:200, 75c., f. o. b. Philadelphia; Sanitary Fluid 1:100, 75c., f. o. b. Hammond, Ind. As prices may change and concessions may be made, the sheepmen should not depend upon these quotations. Crude carbolic acid, including soap and sal soda, will cost about 40c. While it is much cheaper, still the trouble of making it up stands in the way of its general use.

Cooper's Powder Dip must be considered by itself. It answers the first requirement. Altho its action is slow, yet it has the compensating quality of remaining in the wool as a continuous and active poison. On account of this, one dipping with it apparently comes nearer to eradicating the tick than one dipping with the coal-tar dips. Regarding its action on the sheep, it must be said that it will take the skin off if it is not properly used. However, I have never seen any such effects when it is used properly in a swimming vat. It must be remembered that the dip contains arsenic which is very poisonous to the sheep and other animals, so that proper precautions must be exercised against its being ingested by the sheep, either by drinking the bath or by eating material upon which they may have been allowed to drain. The latter possibility should be prevented by keeping the sheep in barren pens until they have drained. Care must be exercised in discarding the dip that remains after dipping has been finished. If reasonable care is exercised there is no reason why poisoning should result. However, it must be admitted that, other things being equal, the fact that the dip is highly poisonous to the higher animals, stands against its use, especially by people who have never been trained to exercise care in such matters. It will be objected that a preparation is worthless as a sheep-dip if it is not poisonous, the idea being that the ticks will not be destroyed. Yet this idea is not necessarily true, for it is found that some drugs, such as coal-tar products, may be more poisonous to the lower animals than to the higher. Hence ticks may be destroyed by solutions so weak that comparatively larger quantities of them may be taken by sheep without damage. But, the fact is that the so-called non-poisonous dips are really poisonous even to sheep and proper care must be exercised against their being imbibed.

There have been reported ill effects upon the wool from the use of arsenic compounds. On the other hand, I have seen prize show-sheep dipped in it. And besides, there are show-sheep owners who prefer it to the coal-tar dips, because they think it has less injurious effect

upon the wool than the coal-tar dips. While it is my opinion that there is little ground for thinking it is injurious, providing the dipping is carried out according to directions, yet this point should be determined by careful, systematic experimentation.

The cost of dipping with Cooper's Powder is about twice as great as with the coal-tar dips. It is also harder to prepare the dip for use.

In the light of these facts it is impossible to decide whether Cooper's Powder is preferable to the coal-tar dips. Both will do the work. Yet is desirable to have as wide a margin of safety as is possible and at the same time practical. The fact that Cooper's Powder will remain in the wool exercising its killing power for months is a distinct point in its favor. For this reason, I would suggest that a most effective dip may be obtained by mixing with Cooper's Powder one of the coal-tar dips in about half or one-quarter the strength recommended for their use. In this way the quick action of the coal-tar dip is combined with the prolonged action of the arsenic and a dip ideal in killing action is obtained. This, however, increases the cost considerably. The first dipping could be made with Cooper's straight or with a coal-tar dip straight and the last with the combination mentioned. In this way the cost would be kept down while the margin of safety would remain wide. Still I would add that there is almost no doubt that two dippings, either with the coal-tar dips or with Cooper's Powder, will absolutely destroy the ticks.

The decision may be left with the sheep men, believing that they will get the desired results whichever method they use, provided reasonable care is exercised and the cautions to be mentioned later are observed.

The last question propounded is, "How many dippings are necessary and when should they be made in order to eradicate the sheep-tick?"

It is certain that one dipping cannot invariably be depended upon to eradicate the tick. Judging from the

facts obtained regarding the normal life-history of the tick and the data concerning the action of sheep dips, at least three dippings would be necessary to make the eradication absolutely certain in all cases; these dippings to be made about fourteen days apart. This conclusion is based upon the facts that in warm weather the pupae require from 19 to 23 days to hatch and a young tick may reach sexual maturity and lay its first pupa in 14 days. Thus it is plain that the second dipping, 14 days after the first, will kill any young tick which may have hatched after the first dipping, before it has had time to lay a pupa. And the third dipping being placed about 12 or 14 days later will occur after all the pupae have hatched and before will have laid pupae. Thus all the ticks will *certainly* be destroyed.

Nevertheless, although the normal life-history indicates that at least three dippins are necessary to insure absolute eradication, there are reasons for believing that the same can be accomplished with two dippings. The eradication of the sheep-tick will be a much lighter burden if it can be accomplished with two dippings.

As a matter of fact, the *normal* life-history should not be used as a basis for determining how many dippings are necessary, because the first dipping modifies the *normal* life-history. The modifications may be set forth as follows: (a) None of the pupae hatch for a couple of days after they are dipped, and if they did, they would be killed in the wet wool; (b) many of the pupae are killed by the first dipping and some are so weakened that the young ticks hatching out never mature. Therefore, the number of pupae hatching out and maturing in a flock during the first two weeks following the first dipping is very small; (c) since the number is small, the chances for a female to become fertilized soon after hatching are slight. It can be shown that these conditions are unfavorable to an early deposit of pupae after the first dipping. Since at least 14 days are required for a young tick to mature and lay its first pupa under the most favorable conditions where males and females are kept together in a small area on a sheep, it is highly prob-

able that at least three weeks would be required under the conditions that follow the first dipping. It has been shown that pupae under four days of age are killed by dipping. Therefore, if a young tick should manage to lay a pupa three days before the last dipping took place, it would be killed. It appears, therefore, that if the second (or last) dipping be placed (in warm weather) 24 days after the first, all ticks will be destroyed.

These theoretical results are supported by some actual dipping tests. In one experiment with Zenoleum two dippings 23 days apart eradicated the ticks. In another experiment with Zenoleum two dippings 31 days apart destroyed the ticks. In a test with Chloroleum and Chloro-naptholeum, two dippings 28 days apart were successful. Two dippings with Cooper's Powder, 38 days apart, were effective. Likewise, one dipping in Cooper's Powder followed in 38 days by a dipping in a combination of Cooper's Powder and Zenoleum destroyed the ticks. We conclude, therefore, that during warm weather the most favorable interval between the first and second (last) dipping is 24 days. If the dipping is done before May or after September the eradication will be less certain and a more favorable interval would be 26 days. While the tick may be destroyed by two dippings with Cooper's Powder 38 days apart, yet the most favorable interval would be that mentioned above.

In regard to the time of year when dipping should take place, it appears that the early fall is the most acceptable. On account of lambing and shearing the spring is unfavorable. It is bad to dip just before lambing or shearing, or just after. If dipping takes place after lambing and shearing it is much harder to eradicate the ticks because of the short wool on the lambs and sheep. In the fall the wool will be long enough on both to hold sufficient dip to make the destruction of the ticks certain. Therefore, marketing time, say the month of September, is the most favorable time for cleaning up the ticks. It is certain that during this next September every sheep-tick in the state could be destroyed so that in the following spring lambs would not face a tick. If the ticks are

once eradicated from a flock of sheep, the flock will remain absolutely free as long as they are not contaminated by ticky sheep.

The question of compulsory dipping for sheep-ticks is a live one and perhaps ought to reecive some consideration in this paper. At this time, when personal liberty is being curtailed on every side by law, it is hard to say whether dipping for sheep-ticks should be made compulsory. There are certainly two sides to the question. Yet, were it not for the fact in this case that the permission of the personal liberty of one sheep-owner to raise sheep-ticks on his sheep may take away the personal right from a neighbor, or more correctly *several* neighbors to maintain their sheep free from sheep-ticks, we would at once say that compulsory dipping is not justifiable. But a flock of sheep infested with sheep-ticks is ever a menace to the flocks that have been freed from this pest, and in a civilized state, it, therefore, becomes the duty of the government out of justice to those who wish to maintain clean flocks either to compel those who own infested flocks to eradicate the pest or to keep their sheep off the public domain and away from clean flocks.

It is probably true that the sheep men are more apt to look at this question from the financial standpoint than that of personal liberty. If so, there can be little doubt as to where everyone ought to stand. Will it pay the sheepmen? Will the cost of eradicating the sheep-tick be as great or greater than the damage done by the tick each year, plus the expenditure that is already being made every year in dipping with only a *partial* eradication? As it is now, all up-to-date sheepmen are spending something every year in dipping and must continue to do so unless every owner will decide voluntarily, or is compelled, to eradicate the tick once and for all time from his flock. If those who do not dip were compelled to, and those who are dipping would voluntarily clean up all their ticks this year, the latter class would be saved all the yearly expense of dipping, while the former class would be gainers also in escaping the damage the sheep-tick is doing in their flocks. There can be no doubt

that the sheep-tick does more damage in a year to a flock of sheep than it would cost to give the flock two dippings. And so in ten years the saving would be almost ten times the cost of giving the sheep the two dippings the first year; for they would not need dipping again, provided the neighbors were compelled to remove their menace. The consensus of opinion is that the sheep-tick does more damage in a year to a flock of sheep than the cost of giving the flock two dippings. Since the cost of eradication of the sheep-tick is unquestionably less than the loss sustained on account of its presence, and since history and present observation indicate that there will be some careless individuals who will not volunteer to clean up their flocks, it would seem advisable for the government to compel proper dipping. Moreover, the government would be especially justified because it would be attempting a perfectly practical and possible work. The task is different from that of eradicating scab and the *true* tick, because the sheep-tick does not spread so insidiously and can be destroyed much more easily. The sheep-tick is not lurking around in crevices, in the bedding and vegetation as is the case with the scab mite and the *true* tick. In fact, altho it is not advisable to do so, the sheep after being dipped may be turned back into the same pens which they occupied before dipping. In all those experiments in which the sheep-tick was eradicated, the sheep were returned immediately after dipping to their old pens.

And so, seeing what has been accomplished by the fight against scab, we are convinced that the sheep-tick can be utterly eradicated from the state within one year after the work has been initiated and systematized. The ticks having been once eradicated from a flock, there is no reason why the owner should be compelled to dip again, unless his flock should become re-infested. And this will not occur if they are kept away from ticky sheep.

Directions for Dipping.

(a) Where a large number of sheep are to be dipped, a swimming vat is indispensable. Directions for building a vat may be obtained from the U. S. Department of Agriculture, Bureau of Animal Industry, Washington, D. C. The sheep should be allowed to swim thru the vat and should be completely submerged twice. In case any extreemly poisonous dip, such as arsenic, is being used, care should be taken that the sheep do not get under and swallow it. If the proper care is exercised, there is no excuse for sheep becoming poisoned. Some sheepmen object to dipping, saying that the loss from poisoning more than balances the gain from destroying the tick. Such results must be due to gross carelessness.

(b) After the dipped sheep have drained well, they should be turned into a yard where no fodder can be contaminated with the poison. This applies especially to arsenic dips. Equal care must be execised in the disposal of arsenic dips.

(c) During the dipping the strength of the bath should be kept as nearly constant as possible. Undoubtedly baths, whether they be emulsions, solutions or suspensions become weaker and weaker as dipping progresses. In the case of emulsions and suspensions, drops and particles of the active agents are filtered out by the wool so that the bath becomes weaker and weaker. And surely even solutions are weakened by the grease from the wool and by organic material (manure) which collects in the bath. At present there are no data upon which to base a rule for correcting this difficulty. It may be said that the bath should be frequently replenished.

(d) In making up the bath and in replenishing it, no guess wark should be allowed. The water and the dip should be carefully measured and used in the proper proportions.

(e) The dipped sheep should be kept absolutely separated from the undipped. They must not be allowed around the shearing grounds or to come in contact with shorn fleeces, which contain pupae that will be hatching for a month.

(f) It is best not to turn the dipped sheep back into the pen, where they were before dipping, within four days.

(g) An attendant should not go amongst dipped sheep after being with the undipped. Ticks might be carried on the clothing. Likewise, dogs should not be allowed to go from undipped to dipped sheep. And moreover, the dogs themselves ought to be dipped along with the sheep.

(h) If sheep are bought or borrowed from another flock, they should be properly dipped before being turned in with clean sheep, unless proper proof that they are clean can be secured.

(i) A record should be kept of the groups of sheep dipped and the day on which each group was dipped, so that no mistakes will be made regarding the interval between dippings.

(j) Dipping should be finished as soon as possible after it has been begun so as not to have on hand for a long time any undipped sheep, which may be a source of infection.

If each person will do his part, in one year the sheep-tick may be eradicated from the state, or for that matter, from the United States. It is, therefore, the duty of everyone, if for no reason other than kindness to the sheep, to eradicate the tick from his flock.

I am indebted to my successor, Dr. J. W. Scott, for inspecting some of the dipped sheep after I left the Experiment Station.

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I. Cottonseed Cake vs. Cold Pressed Cottonseed Cake for Beef Cows.

II. Mixed Grains vs. Cottonseed Cake for Growing Beef Cattle.

By A. D. FAVILLE.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyoming.

UNIVERSITY OF WYOMING

Agricultural Experiment Station

LARAMIE

PART I. COTTONSEED CAKE VS. COLD PRESSED COTTONSEED CAKE FOR BEEF COWS.

PART II. MIXED GRAIN VS. COTTONSEED CAKE FOR GROWING BEEF CATTLE.

PART I.

Introduction.

Within the last few years cottonseed products have come into common use thruout many parts of Wyoming and the question is often raised as to the relative merits of these stock concentrates. The two bi-products, a test of which is reported in the following pages, find many buyers among both cattle and sheepmen. Cottonseed cake is the residue of the cottonseed kernel after the hull has been removed and the oil extracted. When ground it is known as cottonseed meal. "Cold-pressed cottonseed cake is produced by subjecting the entire uncrushed, unheated seed to great pressure. In the residual cake there is a larger proportion of hull to meal than in normal cake with a correspondingly lower feeding value."*

A study of the following composition table brings out the difference in the two products:

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*Henry's Feeds & Feeding.

TABLE "A." ANALYSIS OF FEEDS.*

Percentage composition, air-dry substance.

FEED	Water:	Ash:	Crude protein:	Crude fiber:	Nitrogen free extract:	Ether extract:
Cottonseed cake	7.66	6.22	41.38	11.69	26.72	6.33
Cottonseed cake cold-pressed	7.68	4.43	25.39	27.79	29.01	5.70

Cottonseed cake runs high in crude protein and low in fiber, while the cold-pressed cake is much lower in protein and higher in fiber.

Outline of Experiment.

The available station beef cows, eight in number, were divided as evenly as possible into two lots. Lot I. contained 1 Shorthorn, 2 Aberdeen Angus, and 1 Hereford. Lot II. had 1 Shorthorn, 2 Herefords, and 1 Angus. Difficulty was experienced in arranging satisfactory groups due to the fact that a number of cows were due to freshen shortly after it was planned to begin experiment. Some of these animals were not included in the lots while others were dropped out at the end of six to fourteen weeks. Individual weights and records were kept in all cases.

An analysis of the cottonseed products has already been given. Native hay of good quality was fed. It was obtained near Laramie (from the Greaser ranch) and was very similar to that obtained in previous years. The cows were kept in a comfortable barn at night and turned out during the warmer part of the day. Both lots were run together during the time they were out of doors.

*Analysis by F. E. Hepner.

RESULTS.

Table "B" shows the initial weights and the gains made by the cows in each lot, also the length of time they were on experiment.

TABLE "B." WEIGHTS AND GAINS.

LOT I. Cold-pressed cottonseed cake	Weight at beginning lbs.	Weight at close lbs.	Gain lbs.	Weeks on experiment
Shorthorn	1226	1285	59	16
Aberdeen Angus	1091	1165	74	12
Aberdeen Angus	981	1090	109	16
Hereford	1515	1540	25	6 *
Total	813	5080	267	50
LOT II. Cottonseed cake.				
Shorthorn	1327	1345	18	16
Hereford	1251	1335	84	16
Hereford	950	1070	120	16
Aberdeen Angus	1150	1246	96	14
Total	4678	4996	318	62

*This cow aborted.

Animals in Lot I. averaged heavier tho, as was previously stated, divisions were made as carefully as possible and from the standpoint of the individuals composing them it appeared to be a fair arrangement.

The lot on cottonseed cake made the heavier gains but the cows in the group were on experiment longer (12 weeks) than were those getting cold-pressed cottonseed.

Taking the total gain of each lot and dividing by the total number of weeks on experiment gives the average weekly gain each animal made for the whole period.

Lot I. (Cold-pressed Cottonseed Cake) Average gain per cow per week, 5.34 lbs.

Lot II. (Cottonseed Cake) Average gain per cow per week, 5.13 lbs.

In other words the animals in Lot I. made an average gain of 5.34 lbs. per week during the time they were on experiment while those in Lot II. put on 5.13 lbs. per week during the time they were tested.

It will thus be seen that gains were practically the same with both lots.

What were the feed requirements that produced these gains? Table "C" furnishes information on this point.

TABLE "C." TOTAL FEED REQUIREMENTS.

LOT I. Cold-pressed cottonseed cake	Hay fed lbs.	Waste hay lbs.	Grain fed lbs.	Weeks on experiment
Shorthorn	2030	36.5	334.5	16
Aberdeen Angus	1475	5.5	250.5	12
Aberdeen Angus	2035	16.0	334.5	16
Hereford	739	5.0	124.5	6
LOT II. Cottonseed cake.				
Shorthorn	2035	13.5	250.5	16
Hereford	2125	19.0	250.5	16
Hereford	2035	10.0	250.5	16
Aberdeen Angus	1755	21.0	222.5	14

The weekly ration per cow per week during the time the animals were on experiment works out as follows:

LOT I.

Pounds native hay per week	125.6
Pounds cold-pressed cottonseed cake per week	21.

LOT II.

Pounds native hay per week	128.2
Pounds cottonseed cake per week	15.7

The hay ration was practically the same for both lots and the amount left was extremely small. Lot I. received three pounds of cold-pressed cake per day while Lot II. received about two and four-tenths pounds.

In round numbers two and four-tenths pounds of cottonseed cake such as was used in this trial, when fed with native hay, gave practically the same results as three pounds of the cold-pressed cake. This seems to agree with the results one would expect from a study of the analysis of the two feeds.

With these facts in mind and knowing local prices it becomes an easy matter to compare the concentrates as to their feeding value.

PART II.

MIXED GRAIN VS. COTTONSEED CAKE FOR GROWING BEEF CATTLE.

Introduction.

Winter rations for Wyoming young stock are often composed largely of native hay, a small grain allowance being occasionally fed as a supplement to this roughage. What available grains are most satisfactory for young beef stock when native hay is utilized? As was stated in Part I. cottonseed products find extensive use in many parts of the state. The cake is easily handled and cattle will waste very little even when fed directly from the ground. Mill run bran and corn are both staples thruout large areas of the West. How do these concentrates compare when fed with our western native hay?

Outline of Experiment.

The cattle used in this experiment were heifers kept in the college herd. Each of the two lots consisted of two Aberdeen Angus and two Polled Herefords.. Lot I. averaged ten months and eight days in age while Lot II. averaged nine months and twenty-nine days. The preliminary feeds were the same in all cases and consisted of a mixture of the three concentrates tested later. Individual records were kept and every attempt was made to have the two lots as uniform as possible. Both the initial and final weights represented an average of the weights for three successive days. Single weighings were taken every two weeks. The feeding period lasted 141 days.

TABLE "A." COMPOSITION OF FEEDS USED IN EXPERIMENT.*

Percentage composition, air-dry substance.

FEED.	Water	Ash	Crude protein.	Crude fiber.	Nitrogen free extract.	Ether extract.
Corn meal	10.20	1.59	10.02	2.67	71.94	3.58
Bran**	9.13	5.10	16.93	7.33	57.68	3.83
Cottonseed cake	7.51	5.87	40.77	11.66	26.19	8.00
Native hay***	6.63	6.70	8.86	30.21	45.32	2.28

*Analysis by F. E. Hepner.

**The bran was what is known as mill feed or mill run bran No attempt had been made to separate the bran and middlings.

***Figures taken from previous analysis.

Both lots had native hay. Lot I. received a grain mixture consisting of equal parts of corn meal and bran; Lot II. ate cottonseed cake.

RESULTS.

The weights and gains of the individuals in each lot are shown in Table "B."

TABLE "B." WEIGHTS AND GAINS (141 days.)

No. of animal.	Breed.	Weight at beginning lbs.	Weight at close lbs.	Total gain lbs.
LOT I. Corn and bran				
203	Hereford	580	719	139
204	Hereford	758	850	92
205	Angus	468	620	152
215	Angus	444	600	156
Average		562.5	697.3	134.8
LOT II. Cottonseed cake				
153	Hereford	741	805	64
206	Hereford	407	508	101
179	Angus	507	585	78
200	Angus	470	615	145
Average		531.3	628.3	97

Lot I. receiving corn and mill run bran averaged considably better gains than did Lot II. getting the cottonseed cake. Native hay was used rather than alfalfa because of the fact that it is the common Wyoming roughage.

The amount eaten by each animal during the feeding period is shown in Table "C."

TABLE "C." AVERAGE FEED EATEN AND LEFT (141 days.)

Lot.	Hay offered lbs.	Grain offered lbs.	Waste hay lbs.	Waste grain lbs.
I. Corn and bran	1279	564	72	1.6
II. Cottonseed cake	1292	282	61	30.

One animal in Lot II., No. 206, almost always left some cake, the others cleaned theirs up in good shape. Hay was of a quality above the average, hence little was wasted. The average daily ration per heifer worked out as follows:

Lot I. Hay 9.1 lbs., Corn and Bran 4. lbs.

Lot II. Hay 9.2 lbs., Cottonseed Cake 2 lbs.

The average weight of Lot I. for the period was 630 lbs., while Lot II. averaged 580 pounds.

The animals were not on a heavy ration as it did not seem desirable to feed for extremely rapid growth.

TABLE "D." FEED FOR 100 LBS. GAIN. (Waste deducted.)

Lot.	lbs. Hay	Corn lbs.	Cottonseed cake lbs.	Mill run bran. lbs.
Lot I. Corn and bran	896	209		209
Lot II. Cottonseed cake	1269		260	

It is to be expected that feed requirements for a pound of gain will be rather high when native hay is used and the grain ration is small.

Some interesting cost figures were obtained using prices prevailing in Laramie during the time of the experiment. With native hay at $12.00, corn meal at $30.00, mill run bran at $30.00 and cottonseed cake at $35.00 per

ton it cost $11.64 to put 100 pounds gain on the animals of Lot I. and $12.16 to put the same gain on those of Lot II. Figuring hay at $6.00 per ton instead of $12.00 and leaving the other prices the same, a 100 pound gain in Lot I. cost $8.95 and a corresponding gain in Lot II., $8.35. With hay high in price the ration used for Lot I. proved somewhat cheaper but with hay low the cottonseed ration was a trifle less expensive. Stated in another way, with native hay high and concentrates at the prices given one pound of cottonseed cake gave smaller and more expensive gains than two pounds of a mixture of equal parts of corn meal and mill run bran. With hay low in price and no change made in price of concentrates, while the cottonseed ration still gave the smaller gains, they were a trifle less expensive than were those obtained when the corn and bran were fed.

ACKNOWLEDGEMENT.

The author wishes to acknowledge his indebtedness to Mr. Frank E. Hepner, the Assistant Station Chemist, who made the analyses of the feeds used in these experiments.

CONCLUSION.

In rations for beef cows two and four-tenths pounds of cottonseed cake when fed with native hay proved practically equal in feeding value to three pounds of cold-pressed cake.

Page 7.

In growing rations for beef heifers a ration of four pounds of a mixture of equal parts of corn meal and mill run bran gave better gains than did two pounds of cottonseed cake.

Page 9.

Under certain conditions the ration in which the grain mixture was used made the cheaper gains; under other conditions the cottonseed ration was more economical.

Pages 10-11.

UNIVERSITY OF WYOMING

AGRICULTURAL
EXPERIMENT STATION

LARAMIE, WYOMING

BULLETIN NO. 107

SEPTEMBER 1915

SWINE FEEDING

I. (a) Pea Pasture for Fattening Pigs.
(b) Hurdling Pea Pasture for Pigs.

II. (a) Alfalfa Tea for Growing Pigs.
(b) Corn Meal vs. Barley Meal for Fattening Pigs.

III. (a) Pea Hay vs. Alfalfa Hay for Brood Sows.
(b) Alfalfa Meal in Fattening Rations for Sows.

A. D. Faville

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyoming.

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CONCLUSIONS.

Pea pasture gave good returns in fattening rations. .... Pages 18-19.

Hurdling pea pasture effected a large saving of peas. .... Pages 18-19.

Pigs that had been on pasture previously made better gains when put on dry feed than did pigs that had had no pasture. .... Page 20.

Returns from an acre of pea pasture were good. .... Page 21.

Cross-bred and pure-bred pigs made practically the same gains. .... Page 21.

Alfalfa tea added to a ration increased gains though it did not appear to be of much value. .... Pages 23-24.

Barley meal proved equal to corn meal for young fattening pigs. .... Page 25.

Alfalfa hay gave better returns in maintenance rations for brood sows than did pea hay. .... Page 26.

A mixture consisting of four parts corn meal and one part alfalfa meal proved less satisfactory as a fattening ration for brood sows than did corn meal alone. Page 27.

Ration Experiments With Swine.

INTRODUCTION.

Pork production is not receiving the attention within our state that the industry merits and farmers are slow in utilizing the pig to convert their crops into a concentrated, readily marketed, product. Work along lines similar to those outlined in Bul. 96 has been continued with the idea of adding material to that already collected relative to the possibilities of swine raising in Wyoming, for pasture crops and home-grown feeds must be considered in the formulating of cheap rations

Statements of results have been condensed as much as possible and the whole bulletin has been shortened with the idea of making it more readable for the average individual. Feeding was done and records were kept by R. P. Allen, who did his work in a careful, painstaking manner.

PART 1.

(a) *PEA PASTURE FOR FATTENING PIGS.*
(b) *HURDLING PEA PASTURE FOR PIGS.*

OUTLINE OF EXPERIMENT.

No attempt will be made in the discussion of this experiment to arrange results under headings (a) and (b), as the tables may be readily split up if so desired.

Twenty-one thrifty shoats were carefully divided into three lots. There were both grade and pure-bred Duroc-Jerseys in each lot; the grades were three-fourths Duroc and one-fourth Tamworth, all of the pigs being out of the same Duroc boar. The 10 grades were from one litter, while the others were from different sows. Each lot had one rather small animal. Lot I had 4 grades and 3 pure-breds; Lots II and III, 3 grades and 4 pure-breds.

TABLE "A." DIVISIONS MADE AND FEED USED.

Lot.	No. in lot	Av. wt. per head	Feed used	
			Pasture	Grain
I.	7	65.	Pea, hurdled	Middlings, 1 part Corn meal, 2 parts
II.	7	67.3	Pea, not hurdled	Same as Lot I.
III.	7	68.4	No pasture	Same as Lot I.

The peas were a fair stand. At the beginning of the experiment, October 12th, the vines were dead. Most of the pods were well filled. The peas for Lot I were hurdled off so that the pigs had access to fresh vines at short intervals. Lot II was given the run of its entire field and Lot III on dry feed had a yard no larger than was needed for exercise. An attempt was made to see whether it would pay to hurdle off a pea field rather than to allow the pigs to run at large.

Small V-shaped portable houses furnished shelter for the lots on pasture and were found very satisfactory. Severe winter weather with a good deal of snow was experienced before the close of the experiment on February 1st, yet the pigs seemed to suffer little from the cold. Whenever there was a chance for them to get out they would be found working over the pea vines. Lot I cleaned up the peas a trifle better, though Lot II did its work well.

Each of the pasture lots containing 1.47 acres furnished grazing for 7 pigs for 112 days, the pigs being on a half grain ration.

At the close of the 16 weeks both pea lots were taken in and put on a full grain ration similar to that received by Lot III. This was done with the idea of determining the residual effect of the pastures.

An analysis of the feeds used in all experiments will be found in the back of this bulletin.

RESULTS.

Lot I on grain and pea pasture, hurdled.

Lot II on grain and pea pasture, not hurdled.

Lot III on grain alone.

Table B shows the weights and gains of the pigs during the 16 weeks that Lots I and II were on pasture.

TABLE "B." AVERAGE WEIGHTS AND GAINS OF PIGS. (112 DAYS).

LOT	Av. wt. at beginning lbs.	Av. wt. at close lbs.	Av. gain lbs.	Average daily gain lbs.
I. Peas hurdled	65.	174.	109.	.97
II. Peas, not hurdled	67.3	157.3	90.	.80
III. No peas	68.4	156.9	88.5	.79

Lots I and II, receiving pea pasture and half the grain ration given Lot III, made better gains. In comparing the first two lots we found that hurdling the peas apparently gave much better results.

TABLE "C" TOTAL AND DAILY GRAIN RATION. (112 DAYS).

LOT	Corn 2 parts	Middlings 1 part
	Total grain per head lbs.	Daily grain per head lbs.
I. Peas, hurdled	272.	2.4
II. Peas, not hurdled	272.	2.4
III. No Peas	544.	4.8

The average weight of the pigs was approximately 115 pounds. The plan followed was to keep Lot III eating as much as possible while the other two lots received one-half the amount Lot III consumed.

During the worst of the weather the pigs on pasture did very little foraging, hence gains were probably somewhat slower and pasture returns not quite as large as they would have been under milder climatic conditions.

TABLE "D." GRAIN FOR 100 POUNDS GAIN.

LOT	Corn lbs.	Middlings lbs.	Total grain lbs.
I. Peas, hurdled............	167	83	250.
II. Peas, not hurdled........	201	101	302.
III. No peas	410	205	615.

Both pasture lots required a much smaller grain allowance for a given gain than did Lot III which received only grain.

365 pounds or approximately 59% less grain was required for 100 pounds gain when pea pasture, hurdled, replaced half the grain ration.

313 pounds or approximately 51% less grain was required for 100 pounds gain when pea pasture, not hurdled, replaced half the grain ration.

Comparing Lots I and II we find that 52 pounds or approximately 17% less grain was required for 100 pounds gain when the pea pasture was hurdled.

Working out the pasture results from the previous tables it will be found that 1.47 acres of pea pasture hurdled made a direct saving of 2788 pounds of grain and 1.47 acres of pasture not hurdled saved 1970 pounds of grain. One acre of hurdled pasture saved 1897 pounds of grain while one acre of the pasture not hurdled saved 1340 pounds.

Residual pasture effects must be estimated before complete returns are given. Results reported in the next section throw light on this subject.

RESULTS.

Each Lot on a Full Ration No Pasture.

At the close of the pasture experiment Lots I and II were brought in and placed on a full grain ration similar to the mixture they had been receiving. Results condensed as much as possible are shown in Table E.

TABLE "E." ALL LOTS ON DRY FEEDS. (56 DAYS).

LOT	Av. daily gain per pig lbs.	Av. daily grain per pig lbs.	Grain for 100 lbs. gain lbs.
1. Peas, hurdled previously............	1.37	6.75	494
II. Peas, not hurdled previously.......	1.28	6.13	479
III. No peas	1.04	5.66	546

It will be seen at once that both pasture lots made considerably better gains than did Lot III which had been on dry feed continuously. That their appetites were better is shown by the fact that their daily grain rations were heavier. And yet taking this into consideration we find grain requirements for 100 pounds gain lower with Lots I and II than they were with the lot that had not been on pasture. The better showing made by the first two lots should be credited to the residual effect of the pasture. Crediting this saving to the pasture account of each lot the residual saving for lot 1 was 278 pounds and for Lot II 335 pounds. The total amounts that may be credited to the pasture are as follows:

1.47 acres pea pasture hurdled, (Lot 1) saved 3066 pounds mixed grain.

1.47 acres pea pasture not hurdled (Lot II), saved 2305 pounds mixed grain.

Stated with one acre as the unit:

Lot I, 1 acre saved 2086 pounds grain.

Lot II, 1 acre saved 1568 pounds grain.

Pea pasture is certainly a valuable aid in the production of cheap pork, and the financial returns from an acre are good.* Hurdling the peas effected a saving equivalent to 518 pounds of grain per acre.

A COMPARISON OF THE GRADE AND PURE-BRED PIGS.

The grade and pure-bred pigs in the pasture experiments, bred and divided as outlined on page 16, were weighed separately thruout the trials. Individual records of the feed eaten were not kept but the figures showing weights and gains may be of interest.

TABLE "F." GRADE VS. PURE-BRED PIGS.

	10 Cross-breds	11 Pure-breds
(Two lots on posture. One lot on dry feed.)		
Average weight when put on pasture....	54.2	78.5
Average weight at end 112 days.........	149.8	174.4
Average gain..........................	95.6	95.9
(All lots on dry feed.)		
Average weight at end of next 56 days...	218.6	244.3
Average gain..........................	68.8	69.6
Average total gain, 168 days............	164.4	165.8

The ten cross-bred pigs divided as follows: four in Lot I and three in Lots II and III, gained an average of 164.4 pounds apiece, while the eleven pure-breds, three of which were in Lot I and four in each of the Lots II and III, gained 165.8 pounds apiece. Both while on pasture and on dry feed, gains made by the two classes were practically the same.

*See Wyo. Bul. 96 for additional data.

PART II.

(a) *ALFALFA TEA FOR GROWING PIGS.*

Outline of Experiment.

Eight late spring pigs, seven of them cross-breds and one pure-bred, were divided as carefully as possible into two lots of four each. The cross-breds were three-fourths Duroc-Jersey and one-fourth Tamworth, while the pure-bred was a Duroc-Jersey. Lot II contained the pure-bred.

The grain ration consisted of a mixture of one part corn meal and one part middlings. For Lot I this feed was mixed with water before feeding, while with Lot II alfalfa tea replaced the water. Alfalfa tea was made by mixing meal and cold water together then allowing the combination to stand from one feeding period to the next. When ready for use the water was strained off thru two thicknesses of cheese cloth and added to the grain allowance.

An analysis of the tea will be found in the back of the bulletin. About three pounds of meal and twenty pounds of water was used in the preparation of each feed. Both lots had good shelter and yards large enough to furnish needed exercise.

The experiment opened November 16th and was continued 168 days.

TABLE "G." DIVISION MADE AND FEED USED.

LOT	No. in lot	Av. weight at beginning, lbs.	Feed Used: 1 part corn meal 1 part middlings
I	4	36.8	Grain mixed with water.
II	4	37.3	Grain mixed with alfalfa tea.

TABLE "H." WEIGHTS AND GAINS. (168 days.)

LOT	Av. weight at beginning lbs.	Av. weight at close lbs.	Av. total gain lbs.	Av. daily gain lbs.
I.	36.8	135.0	98.2	.58
II.	37.3	151.8	114.5	.68

During the 168 days pigs of Lot II receiving the tea gained a trifle over sixteen pounds apiece more than Lot I. It is a question whether this would be enough of a gain to offset the extra cost and work. Gains were rather small with both lots. The pigs seemed to lack a trifle in appetite and general thrift. Lot II, getting the tea, ate somewhat better and had noticeably better coats.

TABLE "I." TOTAL AND DAILY GRAIN RATION. (168 days.)

LOT	1 part corn meal, 1 part middlings	
	Total grain per head lbs.	Daily grain per head lbs.
I. Grain mixed with water....	547	3.3
II. Grain mixed with alfalfa tea	547	3.3

The average weight of the eight pigs during the time they were on experiment was approximately ninety pounds. Both lots received the same amount of grain daily though Lot II would probably have eaten a trifle more.

The grain requirements for one hundred pounds gain are shown in Table "J".

TABLE "J." GRAIN FOR 100 POUNDS GAIN.

LOT	Corn lbs.	Middlings lbs.	Total grain lbs.
I. Grain mixed with water....	278.5	278.5	557.
II. Grain mixed with alfalfa tea	239.	239.	478.

Seventy-nine pounds or approximately 14% less grain was required for 100 pounds gain when alfalfa tea was used in the ration. The question comes up as to whether a small amount of the meal itself would not have proven equally satisfactory. While the tea was doubtless of some benefit, was it a product valuable enough to be used in preference to the alfalfa meal itself?

(b) *CORN MEAL VS. BARLEY MEAL FOR FATTENING PIGS.*

Outline of Experiment.

At the close of the test of alfalfa tea the eight pigs used in the experiment were divided into two lots in such a way that both of the new lots had two of the pigs from each old. Lot I averaged 146.8 pounds in weight and Lot II 140 pounds.

The grain rations were made up as follows:

Lot I. Corn meal, 4 parts.
Alfalfa meal, 1 part.

Lot. II. Barley meal, 4 parts.
Alfalfa meal, 1 part.

A condensed statement of the results of the 56 day feeding period is given in Table "K."

TABLE "K." CONDENSED RESULTS. CORN VS. BARLEY. (56 Days).

LOT	Av. daily gain per pig lbs.	Av. daily grain per pig lbs.	Feed for 100 lbs. gain, lbs.
I. Corn meal. 4..... Alfalfa meal, 1..	1.02	4.9	486
II. Barley meal, 4... Alfalfa meal, 1 ..	.98	4.9	500

Making allowance for the fact that one animal in Lot II. was sick for two weeks, we are safe in assuming that barley meal was as satisfactory a pig feed as corn meal. Weights were kept of the sick pig, hence the assumption made is one borne out by figures.The returns as given show but little difference in the two concentrates.

PART III.

(a) *PEA HAY VS. ALFALFA HAY FOR BROOD SOWS.*

Outline of Experiment.

Six station brood sows were devided into two lots and put on rations planned with the idea of testing out the value of alfalfa and pea hay. The test began Nov. 18th and was continued for ninety-one days.

TABLE "L." DIVISIONS MADE AND FEED USED.

LOT	No. in lot	Av. weight at beginning lbs.	Feed used
I	3	254	Grain and alfalfa hay.
II.	3	270	Grain and pea hay.

The hay was fed in racks through the sides of which the pigs could get their noses. There was almost no waste. The grain mixture consisted of two parts of

corn meal and one part middlings fed as a slop.

Small gains were desired as the pigs were rather thin when the experiment opened.

An analysis of feeds used will be found in the back of this bulletin.

Results.

TABLE "M." WEIGHTS AND GAINS. (91 days.)

LOT	Av. wt. at beginning lbs.	Av. wt. at close lbs.	Av. total gain, lbs.	Av. daily gain,[1] lbs.
I. Alfalfa hay...	254	303	49.	.54
II. Peavine hay..	270	309	39.	.43

The average daily ration per pig was as follows:

Lot I. Grain 3.6 pounds, alfalfa hay 1.9 pounds.

Lot II. Grain 3.6 pounds, pea hay 1.9 pounds.

The average weight of the pigs for ninety-one days, was 286 pounds.

The pea hay was fair in quality though the vines were not heavily loaded with pods. Both lots made satisfactory gains and kept in good breeding condition. As will be seen by a study of the above table, alfalfa hay proved to be somewhat better.

The past year's work with maintenance rations again brings out the point that the Wolff-Lehmann standards are too high.

(b) *ALFALFA MEAL IN FATTENING RATIONS FOR BROOD SOWS.*

Outline of Experiment.

It semed wise to dispose of several of the brood sows so plans were laid to test the value of alfalfa meal in their fattening rations. Only five animals were available for the work and no very satisfactory lot divisions could be worked out. Lot I., receiving straight corn meal, contained two and Lot II., getting four parts corn meal and one part alfalfal meal, had three animals. Both lots were in condition to make rapid gains. Table "N" summarizes the results of this test.

TABLE "N." ALFALFA MEAL RESULTS SUMMARIZED. (42 Days).

LOT	Av. daily gain lbs.	Av. daily ration s.	Feed for 100 lbs. gain.	
			Corn meal lbs.	Alfalfa meal lbs.
I................	2.9	11.9	410	
II................	2.1	10.2	389	97

Both lots made heavy gains on low feed requirements. The 97 pounds of alfalfa meal fed to each animal of Lot II. in producing 100 pounds gain replaced 21 pounds of corn meal used by Lot I.

With lots as small and irregular as were these it would not be fair to attempt detailed comparisons. Individuality is too strong a factor in both lots.

ACKNOWLEDGMENTS.

The writer wishes to acknowledge his indebtedness to Mr. F. E. Hepner and to Mr. E. N. Roberts, Assistant Station Chemists, for the analyses of feed tested in the foregoing experiments.

TABLE "O." CHEMICAL COMPOSITIONS OF FEEDS.

FEED	Percentage composition air dry substance					
	Water	Ash	Crude protein	Crude fiber	Nitrogen free extract	Ether extract
Alfalfa meal	7.05	9.31	13.28	35.46	33.76	1.14
Barley meal	9.93	2.78	9 37	5.54	70.57	1.81
Corn meal..	10.03	1.59	10.26	2.85	70.88	4.39
Middlings...	10.32	2.11	13.27	2.67	69.08	2.55
Alfalfa tea.	98.	0.56	.46	0.02	0.96	Trace
Alfalfa hay	6.14	9.48	16.84	28.12	37.13	2.32
Pea hay....	6,21	7.72	13.56	32.42	37.77	2.29

UNIVERSITY OF WYOMING

AGRICULTURAL EXPERIMENT STATION

LARAMIE, WYOMING

BULLETIN NO. 108

OCTOBER 1915

CATTLE FEEDING

I. Oat and Pea Silage in Maintenance Rations for Steers.

II. Oat and Pea Silage for Beef Cows.

III. Oat and Pea Silage for Growing Cattle.

A. D. Faville

Digest.

In rations for steers oat and pea silage when fed with native hay produced much heavier and cheaper gains than did native hay alone. .... Pages 36-37.

Twenty-eight pounds of silage was much more valuable than 10 pounds of native hay in steer rations. Page 36.

Oat and pea silage used with alfalfa hay made a very satisfactory ration for breeding cows of the beef breeds. .... Page 37.

Silage added to a ration of grain and alfalfa for growing beef stock gave cheaper gains than did a grain and alfalfa ration. .... Page 38.

Silage gave remarkably good returns when fed with alfalfa in rations for young cattle. .... Page 40.

Cattle Feeding Experiments

INTRODUCTION.

Maintenance and growing rations are of more interest to most Wyoming cattlemen than are fattening rations. The problem confronting stock growers is one of finding feeds that will winter animals through or carry them in times of storm. Such feeds must be both cheap and satisfactory if they serve their purpose well. Too little effort has been made to keep young breeding stock and steers growing during the winter months. Cattle of this class often lose weight during cold weather and depend on summer pasture for their gains. If conditions can be altered so that winter as well as summer may be made productive of cheap gains, feeding operations are sure to be more remunerative. Native hay is extensively utilized in carrying stock cattle through the winter. No one will deny that it does its work well; yet is it not possible that the addition of some succulent feed like silage would greatly improve the ration?

Alfalfa is one of the very best maintenance roughages. Can silage be made to replace part of the alfalfa to advantage in both growing and maintenance rations? It is hoped that experiments outlined on the following pages may throw some light on the questions raised.

Divisions Made and Rations Used.

Lot I. (6 steers) Native hay.

Lot II. (6steers) Native hay, silage.

Lot III. (4 cows) Alfalfa, silage.

Lot IV. (4 heifers) Grain, alfalfa, silage.

Lot V. (4 heifers) Grain, alfalfa, silage.

Lot VI. (4 heifers) Grain, alfalfa.

Lot VII. (6 heifers, 1 bullock) Grain, alfalfa, silage.

Lot IV was started with four heifers, one calved eight weeks later and so returns were figured on the three remaining animals.

Feeds.

The native hay fed to Lots I and II was coarse and of poor quality. The alfalfa was practically all choice. Lots III and IV received second cutting and the others first. Silage though designated as oats and peas was composed largely of oats. The peas failed to make a satisfactory growth. Water was added to most of the silage material as it was cut into the silo and the ensilage came out in fine shape. Most of the oats were fairly well ripened before being cut. Small amounts of barley and alfalfa were also ensiled with satisfactory results.

The grain fed consisted of a mixture of two parts mill feed, (bran and middlings mixed), one part oats and one part corn meal.

An analysis of feeds used will be found at the back of the bulletin.

Price of Feeds.

Where cost estimates are given native hay is figured at $10 a ton, alfalfa at $12 and silage at $4. Grain is valued at $1.25 per hundred. Knowing the amounts required for a given period it becomes easy to apply local prices when financial estimates are wanted.

Cattle.

The station is indebted to Mr. D. O. Herrick for his kindness in loaning the steers and furnishing the hay which made possible experiments I and II. The animals were two-year-olds, rather thin but of fair quality. Two of the steers appeared to be predominately Angus and the balance showed Shorthorn or Hereford characteristics.

The cows of Lots III and IV were part of the college herd. Lot III consisted of 1 Shorthorn, 1 Aberdeen Angus, and 2 Polled Herefords. Lot IV was composed of 1 Shorthorn, 1 Polled Hereford, and 2 Aberdeen Angus. Heifers in the last three lots included Angus, Herefords, Ayrshires, French Canadians and 1 Jersey. The bullock of Lot VII was an Angus sold later to a local market.

Weights.

Individual records with weighings every two weeks were kept for all the cows and heifers. Lots I and II were weighed at the beginning and at the close of their test. The animals in Lots III, IV, V, VI, and VII were weighed on three consecutive days at the opening and closing of experiments and averages of the three weighings were taken for initial and final weights.

Shelter.

The steers were fed under a shed and had the run of fair sized yards. The cows and young stock were kept in stanchions in the stock barn and allowed to run together in a large sheltered yard during the day.

Method of Feeding.

The steers of Lot I were fed their hay in morning and evening installments. Lots II and III received silage in the morning and hay in the evening. Lot IV had hay morning and evening. The balance of the lots received grain in the evening and hay morning and evening when no silage was fed. When silage formed part of the ration it took the place of the morning hay.

Stock was cared for and records were kept by W. A. Berry and Riley Oakes and credit is due them for the careful way in which the work was done.

PART I. OAT AND PEA SILAGE IN MAINTENANCE RATIONS FOR STEERS.

The common practice throughout large areas of Wyoming where range is limited or snow is deep in winter is to put the cattle into feedlots in the fall and give them native hay during the cold months. With good hay and satisfactory conditions it is surprising to see how well the cattle appear in the spring, especially if they are animals that have most of their growth. When hay is rather poor as is often the case, gains are small and the question then arises as to whether it would not pay to to supplement the hay with some other feed. Grain is generally expensive and alfalfa is not always

to be had. Under these conditions will silage be of value in a native hay ration?

Table I shows the results obtained with two-year-old steers when oat and pea silage replaced part of the native hay.

TABLE I.

Native hay vs. native hay and silage in maintenance rations for steers.

Jan. 17 to March 28, 1914. (70 days.)

	LOT I.	LOT II.
	Native hay.	Native hay, silage.
Avg. initial weight	1054 lbs.	1080 lbs.
Avg. final weight	1096 lbs.	1188 lbs.
Gain per steer	42 lbs.	108 lbs.
Avg. daily gain	.60 lbs.	1.54 lbs.
Avg. daily feed per steer:		
Native hay	25 lbs.	15 lbs.
Silage		28 lbs.
Feed for 100 lbs. gain:		
Native hay	4167 lbs.	974 lbs.
Silage		1818 lbs.
Cost of 100 lbs. gain	$20.84	$ 8.51
Cost of daily ration per steer	12.5 cts.	13.1 cts.

The average gain for Lot I was only 42 pounds per head during the 70 days in which the steers of Lot II receiving ensilage gained 108 pounds apiece. Comparing the daily rations we find that each steer of Lot I was fed 25 pounds of native hay per day against 15 pounds for animals of Lot II.

However, each steer of Lot II was given a daily allowance of 28 pounds of ensilage in place of the extra 10

pounds of hay it should have received had it been getting a ration similar to that received by Lot I. The native hay lot received all the hay it would eat while Lot II had what hay it would clean up during the night.

Feed requirements for 100 pounds gain ran very high with Lot I and rather low for Lot II.

The native hay ration cost 12.5 cents a day, while the hay and silage ration cost 13.1 cents a day. However, the ration costing six-tenths of a cent more increased the daily gain nearly one pound per head. Comparing the two lots as to the cost of 100 pounds gain we find that the combination of silage and hay proved much more satisfactory.

In the appearance of the steers and in the rapidity and cost of gains Lot II had all the advantage. Couple these points with the fact that silage fed animals will show no greater shrinkage than will lots dry fed and we have strong arguments in favor of the succulent ration.

PART II. OAT AND PEA SILAGE FOR BEEF COWS.

A test was made of the silage described in an earlier section to determine its value in rations for breeding cows. Table II gives the results obtained both from rations consisting solely of alfalfa and rations in which silage replaced part of the hay.

TABLE II.

Alfalfa vs. alfalfa and silage for breeding cows.

	LOT III.	LOT IV.
	Alfalfa, silage.	Alfalfa.
Avg. initial weight	1154 lbs.	1246 lbs.
Avg. final weight	1196 lbs.	1318 lbs.
Gain per cow per week	2.5 lbs.	3.9 lbs.
Avg. daily feed per cow:		
Alfalfa	10 lbs.	21.8 lbs.
Silage	15 lbs.	
Cost of ration per cow per day	9 cents.	13 cents.

The experiment was run for 140 days, beginning December 23rd, 1913, and ending May 12th, 1914; but during that time cows in both lots calved and were dropped from the trial. Therefore the gains made are figured on a weekly basis.

Both rations met requirements very satisfactorily. While the 15 pounds of silage fed to each cow in Lot III did not quite replace the 11.8 pounds extra alfalfa animals in Lot IV received, it made a good winter ration for breeding cows and effected a saving of four cents per cow per day.

PART III. OAT AND PEA SILAGE FOR GROWING CATTLE.

Succulence is desirable in rations for young cattle as well as for old. In sections not adapted to corn it must be furnished by means of roots or through the use of some other silage crop. In the feeding tests outlined on the following pages oat and pea silage was used to replace alfalfa in a ration. Table III will show how well it did its work.

TABLE III.

Grain, alfalfa and silage vs. grain and alfalfa for growing beef cattle.

Dec. 23, 1913, to May 12, 1914. (140 days.)

	LOT V.	LOT VI.
	Grain, alfalfa, silage.	Grain, alfalfa
Avg. initial weight	834 lbs.	808 lbs.
Avg. final weight	964 lbs.	950 lbs.
Gain per heifer	130 lbs.	142 lbs.
Avg. daily gain	.93 lbs.	1.02 lbs.
Avg. daily feed per heifer:		
Grain	1.8 lbs	1.8 lbs.
Alfalfa	10 lbs.	18 lbs.
Silage	10 lbs.	
Feed for 100 lbs. gain:		
Grain	195 lbs.	176 lbs.
Alfalfa	1077 lbs.	1762 lbs.
Silage	1077 lbs.	
Cost of 100 pounds gain:	$11.05	$12.77
Cost of daily ration per heifer..	10.5 cts.	13 cts.

Gains were good with both lots, the ration fed to Lot VI putting on 13 pounds more gain per animal during the 140 days of the trial than did the ration in which ensilage was used. The feed requirements for 100 pounds gain ran rather high for both lots due largely to the fact that rations were planned for fair growth rather than for rapid gains.

The ration fed Lot V, consisting of grain, alfalfa and silage, cost less per day and put on cheaper gains than did the grain and alfalfa ration. Silage in this trial proved to be a valuable addition to the ration.

Lot VII consisted of a rather mixed lot of animals that did not seem to fit in well with any of the other groups. In order to test the value of silage as completely as possible five of the animals were fed reversible rations during four-week periods, that is, they were fed silage during one period and no silage during the next, etc. The results obtained by this method of feeding are shown in the following tabulation:

TABLE IV.

Grain and alfalfa vs. grain, alfalfa and silage for growing cattle. Ration changed every four weeks.

Dec 23, 1913, to April 14, 1914, (112 days.)

	Hereford U. W. 218,	Angus U. W. 216,	Ayrshire U. W. 211,	Jersey U. W. 143,	Hereford U. W. 203,
	lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Avg. initial weight	474	549	496	616	947
Avg. final weight	582	725	636	694	1045
Gain 8 weeks with silage	68	89	52	52	86
Gain 8 weeks without silage	40	87	88	26	12
Daily ration with silage, 8 weeks:					
Grain	3	3	3	3	2
Alfalfa	6	6	6	8	10
Silage	5.5	5.5	5.5	10	10
Daily ration, no silage, 8 weeks:					
Grain	3	3	3	3	1.5
Alfalfa	9.5	9.5	9.5	12	18.0

Total gain of 5 head on silage .... 347 lbs.

Total gain of 5 head without silage .... 253 lbs.

Every animal but 211 responded better to the silage ration, the total gain for the lot being 94 pounds more than it was when no silage was fed.

With animals 218, 216 and 211 the silage ration contained 5.5 pounds silage which was replaced in the no-silage ration by 3.5 pounds alfalfa hay. Jersey No. 143 had 4 pounds extra alfalfa per day when 10 pounds silage was dropped; and Hereford No. 203 had 8 pounds extra alfalfa as a substitute for 10 pounds silage.

A careful study of Table IV furnishes convincing arguments for the use of oat and pea silage in rations for growing cattle. In the total daily ration for the five animals 36 pounds silage and 22.5 pounds alfalfa were fed interchangeably with gains considerably in favor of the silage. 1.6 pounds silage took the place of 1 pound choice alfalfa and gave heavier gains. There was practically no waste hay or silage left by any of the cattle.

Two French Canadian heifers of about the same age and weight were put on comparable rations; one consisting of grain and alfalfa, and the other of grain, alfalfa and silage. Table V gives the results obtained with these two individuals.

TABLE V.

Grain and alfalfa vs. grain, alfalfa and silage for growing heifers.

Dec. 23, 1913, to April 14, 1914, (112 days.)

	French Canadian U. W. 145. Grain, alfalfa,	French Canadian U. W. 146 Grain, alfalfa. silage.
Initial weight	576 lbs.	540 lbs.
Final weight	675 lbs.	610 lbs.
Total gain	105 lbs.	70 lbs.
Daily gain	.94 lbs.	.63 lbs.
Daily ration:		
Grain	3 lbs.	3 lbs.
Alfalfa	12 lbs	8 lbs.
Silage		7.9 lbs.

With but one animal on each ration it would be foolish to attempt to draw conclusions. The table may be of interest to some in showing amounts fed, gains made, etc.

ACKNOWLEDGEMENT.

The writer is indebted to Mr. E. N. Roberts, Assistant Station Chemist, for analyses of the feeds used in these experiments. The results he obtained are given in Table VI.

TABLE VI.

Percentage Composition of Feeds Used.

FEED	Percentage Composition Air Dry.					
	Water	Ash	Protein	Crude fiber	Nitrogen, free ext.	Ether extract
Native hay	6.18	6.27	10.50	31.90	43.33	1.82
Alfalfa, 1st cutting	6.35	8.37	11.35	35.32	36.78	1.83
Alfalfa, 2nd cutting	6.17	8.08	14.06	35.39	34.61	1.69
Corn meal	9.20	1.46	10.53	1.67	73.39	3.75
Oats	8.02	3.75	14.25	10.26	58.95	4.77
Mill feed	8.19	5.45	14.28	8.36	58.91	4.81
Oat and pea silage (air dry)	6.21	8.09	9.65	27.05	44.95	4.05
Oat and pea silage (calculated to original water content.	69.73	2.61	3.11	8.73	14.51	1.31
**Russion thistle silage (air dry)	4.83	17.72	5.65	28.68	40.72	2.40
**Russian thistle silage calculated to original water content)	65.64	6.40	2.04	10.35	14.70	.87

**The figures for Russian thistle silage were obtained from a sample of the material brought in from the F. A. Holliday ranch. Mr. Holliday fed the thistle silage to dairy stock and was well satisfied with results. The thistles were cut about September 1st.

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UNIVERSITY OF WYOMING

AGRICULTURAL EXPERIMENT STATION

LARAMIE, WYOMING

BULLETIN NO. 109

NOVEMBER 1915

SHEEP FEEDING

I. (a) Oat and Pea Silage for Fattening Lambs.
   (b) Corn vs. Barley for Fattening Lambs.

II. Oat and Pea Silage for Breeding Ewes.

III. Oat and Pea Silage for Ram Lambs.

A. D. Faville

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyoming.

Digest.

The heaviest gains made by fattening lambs were on a rations of corn and alfalfa. Page 52.

Valuing alfalfa at $12.00 and silage at $4.00 per ton, a ration in which silage was used made as cheap gains in fattening lambs as did the corn and alfalfa ration. Page 52.

Alfalfa and silage without grain did not prove to be a satisfactory fattening rations for lambs. Pages 52-53.

When barley replaced corn in a fattening ration gains were somewhat lower. Page 54.

Oat and pea silage may be used satisfactorily in rations for breeding ewes. Page 56.

In growing rations for ram lambs oat and pea silage may be used to replace part of the alfalfa. Page 57.

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Sheep Feeding Experiment.

INTRODUCTION.

The great silage crop, corn, is grown successfully in few parts of Wyoming. Have we other materials that may be used to advantage in furnishing succulence for our winter stock rations? If satisfactory corn substitutes are found, many parts of the state will find the silo a paying proposition. Experiments outlined on the following pages were undertaken with the idea of throwing some light on the Wyoming silo problem.

Sheep.

The lambs fattened experimentally were ordinary range stuff out of grade fine wooled ewes which had been bred to mutton rams. Altho fairly uniform in type, they were not choice in quality. The breeding ewes consisted of the College purebred flock, a mixture of both Down and Long-wooled breeds. They were in good condition, hence required no more than a maintenance ration. The ram lambs were purebreds from the College flock and represented most of the leading mutton breeds. All lots compared were arranged so as to indicate animals of the same type and breeding.

Shelter.

Good shelter was provided for all lots. The fattening lambs had yards large enough to furnish needed exercise while the ewes and rams had the run of large fields during the pleasant days. All of thè sheep were housed in a dry well-vetilated barn.

Divisions Made and Rations Fed.

Divisions were always planned with the idea of making lots to be compared as uniform as possible. The number of animals in each lot and rations fed were as follows:

Lot I. (25 lambs). Shelled corn, alfalfa, silage.

Lot II. (25 lambs). Shelled corn, alfalfa.

Lot III. (25 lambs). Whole barley, alfalfa, silage.

Lot IV. (25 lambs). Alfalfa, silage.

Lot V. (20 breeding ewes, 1 ram). Alfalfa.

Lot VI. (20 breeding ewes, 1 ram). Alfalfa, silage.

Lot VII. (12 rams). Grain (5 parts mill feed, 2 parts oats, 3 parts corn meal), alfalfa, silage.

Lot VIII. (11 rams). Grain (same as Lot VII), alfalfa.

Feeds.

Corn was shipped in from Nebraska. Scotch barley grown on the Laramie Plains was fed. The alfalfa, both first and second cutting, was of good quality and was grown on farms near the Station. During the latter part of the tests with breeding ewes and ram lambs, alfalfa brought in from Wheatland was fed. It was poor in quality and very coarse. The mill feed, or mill run bran, consisting of a mixture of bran and middlings, was an Idaho product. The oats were also from outside of the state. Oats, through which were scattered a few peas, furnished the bulk of the silage. The crop was harvested when the oats were beginning to turn and a consid-

erable amount of water was added to the silage material. Small amounts of barley and alfalfa, which were also ensiled, came out in good shape. The bulk of the silage fed experimentally consisted of the oats and peas. It kept well and was greedily eaten by cattle of all ages. The sheep were somewhat slow in taking to the silage and it was seldom possible to get them to eat more than a pound a day, even when fed morning and evening.

An analysis of all the feeds used will be found at the back of this bulletin.

During extremely cold weather fresh water was supplied to each lot twice a day; at other times the tubs were filled oftener. Salt was always accessible.

Weight.

Lots I to IV, inclusive, were weighed for three successive days at the beginning and end of the trial and averages of the weights were taken. Single weighings were made every two weeks during the tests. Lots V, VI, VII and VIII were weighed every four weeks.

Methods of Feeding.

All feed troughs and racks were under cover. Hay was placed in long V-shaped racks built so as to catch hay that was pulled out. Silage and grains were fed in narrow troughs. The fattening lambs were given all their feed in morning and evening installments. Lot V had hay morning and evening and Lot VI received silage in the morning and hay in the evening. Lot VII

received grain and alfalfa in the evening and silage in the morning, while Lot VIII had grain in the evening and alfalfa in the morning and evening. The preliminary feed of lots to be compared was always the same. The sheep were in charge of R. P. Allen, who gave them careful attention throughout the trial.

Prices of Lambs and Feeds.

The grade lambs were purchased for $5.50 per hundred and sold locally for $6.25. Had there been enough to ship the price realized would probably have been somewhat better. Feeds have been figured at the following prices: Corn and barley, $1.25 per hundred; alfalfa, $12.00 per ton, and silage, $4.00 per ton.

I. (a) OAT AND PEA SILAGE FOR FATTENING LAMBS.

As was previously stated, the silage consisted chiefly of oats. The lambs were fed all the silage and hay they would clean up with a limited grain ration. By restricting the grain allowance it was thought that the lambs might be induced to eat more silage. Table I shows the comparative value of the various rations:

TABLE I.

Oat and pea silage for fattening lambs.
Nov. 18, 1913, to Mar. 10, 1914. (112 days).

	LOT I.	LOT II.	LOT IV.
	Corn, alfalfa, silage.	Corn, alfalfa.	Alfalfa, silage.
	lbs.	*lbs.*	*lbs.*
Avg. initial weight	46	46.1	45.7
Avg. final weight	73.8	76.2	64.6
Gain per lamb	27.8	30.1	18.9
Avg. daily gain	.25	.27	.17
Avg. daily feed per lamb:			
Grain	.47	.47	
Alfalfa	1.8	2.3	2.3
Silage	.7		.74
Feed per 100 lbs. gain:			
Grain	191	176	
Alfalfa	730	854	1376
Silage	284		439
Cost of 100 lbs. gain	$7.33	$7.32	$9.13

Lot II receiving corn and alfalfa made slightly the best gains while Lot IV, getting no grain, was a poor third. Comparing Lots I and II we find that .7 pounds of silage in one ration replaced .5 pounds of alfalfa hay in the other. Lot IV received the same hay ration as Lot II and .74 pounds of silage was fed instead of .47 pounds shelled corn. The grainless ration did not put on satisfactory gains.

Feed requirements for 100 pounds gain were fairly low with Lots I and II while with Lot IV they ran high, due to the slow gains made. Lot I in comparison with Lot II required 15 pounds more grain and 124 pounds less hay

in addition to 284 pounds of silage to make a hundred pound gain.

Using feed prices indicated previously we find cost of gains practically the same for Lots I and II and much higher for Lot IV. Under conditions outlined for the first two lots, with alfalfa at $12.00 per ton, the silage was worth $4.00. It is possible better silage returns would have been obtained if the lambs had eaten it more freely.

At the close of the 112 day feeding period, Lot IV lacked finish so was put on a grain ration for 28 days. The following figures were collected during this time:

Lot IV, on feed 28 days, Mar. 11 to Apr. 7, 1914.

	Lbs.
Average initial weight	64.6
Average final weight	72.1
Average total gain	7.5
Average daily gain	.27
Average daily rations:	
Shelled corn	6
Alfalfa	2.0
Silage	1.0
Feed for 100 lbs. gain:	
Grain	219
Alfalfa	755
Silage	373

While gains were much better than they had been previously financial returns did not justify the added expense.

(b) CORN VS. BARLEY FOR FATTENING LAMBS.

Barley is a grain that can be grown successfully in most of our western country while the areas adapted to corn culture are extremely limited. Home grown rations are to be desired when practicable, hence compari-

sons between corn and barley are always interesting to feeders outside of the corn belt. Lots I and II furnish comparisons between two rations, one of which was composed entirely of home grown feeds while the other had native roughages with corn as a concentrate. Table II furnishes a comparison of the two rations.

TABLE II.

Corn, alfalfa and silage vs. barley, alfalfa and silage for fattening lambs.

Nov. 18, 1913, to Mar. 10, 1914. (112 days).

	LOT I. Corn, alfalfa, silage.	LOT III. Barley, alfalfa, silage.
Avg. initial weight	46 lbs.	46.3 lbs.
Avg. final weight	73.8 lbs.	71.6 lbs.
Gain per lamb	27.8 lbs.	25.3 lbs.
Avg. daily gain	.25 lbs.	.23 lbs.
Avg. daily feed per lamb:		
Grain	.47 lbs.	.47 lbs.
Alfalfa	1.8 lbs.	1.8 lbs.
Silage	.7 lbs.	.7 lbs.
Feed for 100 lbs. gain:		
Grain	191 lbs.	209 lbs.
Alfalfa	730 lbs.	802 lbs.
Silage	284 lbs.	312 lbs.
Cost of 100 lbs. gain	$7.32	$8.04

Returns from corn were somewhat better throughout the experiment, though differences were not great. Eighteen pounds less grain, 72 pounds less alfalfa and 28 pounds less silage was required for 100 pounds gain when corn replaced barley in the ration and the cost of 100 pounds gain was 72c less with Lot I than with Lot III. Under conditions prevailing in many sections of the state, either ration ought to put on profitable gains.

Part II. OAT AND PEA SILAGE FOR BREEDING EWES.

The sheepman who is compelled to feed his stock throughout the winter or during periods of storm is always interested in the question of maintenance rations for his breeding ewes. A ration to be satisfactory must be one that puts the animal in good breeding condition without putting too heavy a drain on the owner's pocketbook. Succulent feeds are always desirable for breeding stock. Roots or corn silage are used extensively in sections where either crop may be satisfactorily grown. Western rations have usually lacked in succulence. Can this deficiency be met by ensiling crops that thrive where corn cannot be grown and roots are produced at a high cost? A study of Table III may throw some light on the subject.

Lots V and VI, composed of the University breeding ewes, were fed with the idea of comparing a straight alfalfa ration with one in which oat and pea silage replaced part of the alfalfa.

TABLE III.

Alfalfa vs. alfalfa and silage for breedings ewes.

Jan. 3, to Feb. 28, 1914. (56 days).

	LOT V.	LOT VI.
	Alfalfa.	Alfalfa, silage.
Avg. initial weight	185 lbs.	183 lbs.
Avg. final weight	193 lbs.	186 lbs.
Gain per sheep	8 lbs.	3 lbs.
Avg. daily ration:		
Alfalfa	4.5 lbs.	3 lbs.
Silage		1.5 lbs.
Cost per week of keeping one 185 lb. ewe	18.9c	14.7c

Both rations proved to be satisfactory for maintenance requirements. Lot V gained a trifle more but that is to be expected. With Lot VI silage replaced alfalfa pound for pound, hence the total dry matter fed this lot was considerably less. There was apparently no difference in the strength and quality of the lambs dropped by the two lots, the percentage of lambs being unusually high for the whole flock.

At the feed prices established, $12.00 per ton for alfalfa and $4.00 for silage, the cost of feed per week for each animal in Lot V was 18.9c. With the animals in Lot VI getting silage this charge was reduced to 14.7c per head, a saving of 4.2c per week. From the standpoint of economy, with feed priced as indicated, the silage rations proved to be the more satisfactory.

PART III. OAT AND PEA SILAGE FOR RAM LAMBS.

Twenty-three purebred lambs dropped rather late in the spring of 1913 were divided as carefully as possible into two lots and put on growing rations planned to still further test the value of the oat and pea silage previously described.

Table IV gives the chief points of interest brought out in connection with this test.

TABLE IV.

Grain, alfalfa and silage vs. grain and alfalfa for growing rams.

Jan. 3, to Apr. 11, 1914. (98 days).

	LOT VII.	LOT VIII.
	Grain, alfalfa, silage.	Grain, alfalfa.
Avg. initial weight	88.5 lbs.	88 lbs.
Avg. final weight	112.5 lbs.	118.9 lbs.
Gain per lamb	24 lbs.	30.9 lbs.
Avg. daily gain	.24 lbs.	.32 lbs.
Avg. daily feed:		
Grain	.6 lbs.	.6 lbs.
Alfalfa	3 lbs.	4.4 lbs.
Silage	1 lbs.	
Feed for 100 lbs. gain:		
Grain	248 lbs.	193 lbs.
Alfalfa	1221 lbs.	1405 lbs.
Silage	408 lbs.	
Cost of 100 lbs. gain	$11.24	$10.84
Cost of growing rations per ram per week	19.2c	23.7c

The ration fed Lot VII was the cheaper but gains were smaller. The cost of putting on 100 pounds gain was 40 cents cheaper with Lot VIII than it was with Lot VII.

In all cost figures we must not lose sight of the fact that feed prices used probably vary widely from prices prevailing in many parts of the state and re-adjustments must be made to meet local conditions.

The amount of alfalfa fed Lot VII was restricted in an attempt to make the sheep eat more silage, yet it seemed impossible to get them to take large amounts. For this reason the ration supplied Lot VII was consid-

erably lower in feeding value than that given Lot VIII.

Summing up the results obtained from the use of silage in sheep rations during the past year one would not be far wrong in giving it a value of $4.00 per ton when first class alfalfa is worth $12.00. With a larger percentage of peas in the silage its value ought to be correspondingly increased.

ACKNOWLEDGEMENT.

The writer is indebted to Mr. E. N. Roberts, Assistsant Station Chemist, for analyses of the feeds used in these experiments. The results he obtained are given in Table V.

TABLE V.

Percentage composition of feeds used.

FEED.	Water	Ash	Crude protein	Crude fiber	Nitrogen free ext.	Ether extract
Alfalfa	6.14	7.20	11.00	37.33	36.89	1.44
Oat and pea silage	6.21	8.09	9.65	27.05	44.95	4.05
Oat and pea silage, (calculated to original water content)	69.73	2.61	3.11	8.73	14.51	1.31
Corn (whole)	8.81	1.33	9.81	2.01	74.24	3.80
Corn meal	8.66	1.69	10.44	2.05	73.43	3.73
Barley	8.51	3.36	12.40	6.80	66.69	2.24
Oats	7.90	3.64	13.38	10.53	59.85	4.70
**Mill feed	8.30	5.67	15.45	8.09	57.65	4.84

**Called also mill run bran, a mixture of bran and middlings.

BULLETIN NO. 110. . SEPTEMBER, 1916

UNIVERSITY OF WYOMING

AGRICULTURAL EXPERIMENT STATION

LARAMIE, WYOMING

SWEET CLOVER

By T. S. Parsons

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyoming.

UNIVERSITY OF WYOMING

Agricultural Experiment Station

LARAMIE

BOARD OF TRUSTEES

Sweet Clover

By T. S. Parsons.

INTRODUCTION.

Sweet clover is becoming an important crop in Wyoming. It has until recently been considered a weed and a pest to be kept off the farm. As farmers come to understand the nature of the plant better, however, it is becoming more and more popular. It is a good soil builder, can be used as a pasture crop, and can be utilized to good advantage on lands too dry or too alkaline for alfalfa to grow.

Sweet clover will do very well on practically all of the soils of the state, provided they are not saturated or water-logged. The plant will not thrive on soil that is saturated but will do well on soils where the water table is within two feet of the surface. It also does not do so well on loose sandy soils but will usually make as good a crop on poor soils as any other crop that can be grown. It responds to good treatment and fertile soil as well as any other plant and if grown for hay it should be sown on good soil so that a better growth may be obtained. Lime is very essential for the successful growing of sweet clover. Wyoming soils are generally well supplied with this element, therefore sweet clover does well.

It is as a soil improver that the sweet clover has its greatest value. It brings quick results when used as green manure or when grown before another crop. It thrives well on soils lacking in humus, therefore it is valuable for building up these soils. The large fleshy roots of the plant penetrate the soil, breaking up the lower layers, and adding humus to it when they decay, thus improving its texture to a considerable depth below the depth of plowing. Sandy soils as well as heavy clay and hardpan soils can be reclaimed with sweet clover and put in condition for growing other crops. Another factor in favor of sweet clover is that the bacteria on its roots will inoculate the soil for alfalfa.* It is therefore a

*HOPKINS, Soil Fertility, New York, (1910), p. 208.

valuable crop to grow on the land immediately preceding alfalfa. The bacteria not only inoculate the soil but the roots penetrate the soil, breaking it up and aerating it, making a condition more favorable to the growth of the last named plant.

Fig. 1.—Volunteer sweet clover along ditch banks.

There are two varieties of sweet clover quite generally grown: The white, botanically known as *Melilotus alba*, and the yellow, botanically known as *Medicago officinalis*. The white is the most common and the variety generally preferred for either hay or pasture. It grows larger and coarser than the yellow variety. The latter is preferred by some as a hay plant on account of its finer habit of growth. It is now being grown quite extensively over the state. Fig. 2 shows a row of yellow clover between two rows of white.

Sweet clover is also much esteemed as a honey producing plant. It is the only flowering plant that can be grown in waste places and utilized for this purpose. The tendency of sweet clover to occupy vacant land is noteworthy. It is seen on vacant lots, along roadsides, railroad embankments and irrigation ditches.† It does not,

†It is passing out into the open range at least one point in the state.

however, usually occupy cultivated fields or meadows. Therefore, it need not be considered a pest. Cattle and other stock eat it readily when accustomed to it and apparently thrive as well on it as on alfalfa.

Fig. 2—Yellow sweet clover in the middle with white sweet clover on either side. Notice the finer and more compact growth of the yellow variety.

I. Cultural Experiments with Sweet Clover.

Results on Water-Logged and Alkaline Land.

For the past five years some sweet clover has been grown on the Agronomy farm of the Experiment Station. No regular experimental work was attempted until the past two years. Certain portions of the farm not suitable for other crops on account of seepage and alkali were sown. A fair crop, usually about one ton per acre has been obtained from the poorest of these lands. Where sweet clover has been sowed on good soil, uniformly good stands and good yields have been obtained, showing that this crop as well as any other responds to good treatment.

At the east side of the agronomy farm is an area of land consisting of about four acres, which receives consid-

erable seepage from the land above and consequently is too alkaline for the growing of grain crops. According to the farm records this area was sowed to sweet clover in 1908. A fair crop was harvested in 1909 and in 1910, after the writer assumed charge of the work, one and one-half tons of cured hay was procured from this area from one cutting. A good second growth was made but a heavy frost on August 24 prevented a second cutting and no seed was produced. In the spring of 1911 no sweet clover appeared. Sweet clover is a biennial and if not permitted to go to seed the second year no plants will appear the year following. This area has been kept in sweet clover by reseeding every two years. By this method a crop has been cut each year until 1915.

The plots on this land were broken up in the fall of 1914 and in the spring of 1915 were seeded to sweet clover with a light nurse crop. A good growth started in the spring but more than the normal rainfall caused excessive seepage so that the soil became saturated and the seed was entirely killed out. It is very certain that sweet clover will not grow on soil that is saturated. A large body of water standing below these plots prevented drainage. In previous years there was sufficient drainage so that the water table was at least two feet below the surface. This area received no irrigation, the seepage from the irrigated land above providing sufficient moisture.

Immediately adjoining this area, but a little higher, is a piece of land of about two acres. This land is too alkaline for the growing of grain crops. This land was sowed to sweet clover on May 10, 1914, at the rate of 10 lbs. of seed per acre. The ground was not plowed, the seed being drilled shallowly with a Superior grass drill. An excellent stand was obtained and a good growth made the first year. It was decided, however, not to cut the crop. The area was clipped early in the season to keep down the weeds. In 1915 growth started early and the first cutting was made about July 15, a small strip being left for seed. A second cutting was not made. The second crop was about two feet in height when killed by frost. The first cutting yielded at the rate of 3 tons of cured hay to the acre. On account of the excessive rainfall and cool

weather the plants in the strip left for seed continued to grow. They became very coarse and woody but did not mature seed. At the altitude of the station the first crop if allowed to stand usually produces seed. At lower altitudes of the state a first cutting can be made and the second cutting kept for seed.

Results on a Dry Farm.

On May 4, 1911, an area of two acres was sowed to sweet clover on the Holliday farm near Laramie, where the station dry-farm experiments were then being carried on. This crop was sowed at the rate of 10 pounds per acre. The plants made considerable growth that year but not sufficient for cutting. One acre was badly covered by blowing sand; the other acre produced 3700 pounds of hay the following year. Much of the seed on the sand-covered acre came up through the sand the second year, but did not make enough growth to warrant cutting. The experiment was discontinued the end of the second season, the owner taking charge of the land.

Observations in various parts of the state would indicate that sweet clover is a good dry-farm crop. In most sections at least one crop per year can be cut and in many sections two. It is evident that it will make a paying crop on land far too dry for alfalfa.

Effect of Compactness of the Soil.

In the spring of 1914 some experiments with sweet clover along definite lines were begun. The purpose of the experiment was to determine, (1) the value of sweet clover as a fertilizer for crops immediately succeeding it, and (2) its value in a complete crop rotation. Results of these experiments cannot yet be given. Only the methods of soil preparation, seeding and yields can be discussed at this time. Both the white and the yellow varieties were used in these experiments and, so far as the work has progressed, it would seem that the two varieties require the same treatment.

For the fertility experiment one of the acre experiment plots and a triangular plot of one-half acre adjoining it were selected. One-half of the acre plot was devoted

to the growing of field peas and alfalfa, one-quarter to white and one-quarter to yellow sweet clover. The triangular half-acre plot was given entirely to the white sweet clover.

These plots were uniform as to kind of soil and amount of barnyard manure received, and were all spring plowed. The seed beds were prepared and seeding was done on the dates as follows, the plots being designated as Nos. 1, 2 and 3:

April 18. Plots 1 and 2 were plowed 8 inches deep, and Plot 3 was plowed 6 inches deep.

April 19. Plots were harrowed with spiketooth.

April 21. Plots were harrowed with Acme.

April 21. Plots were harrowed with spiketooth.

May 8. Seeded Plot 1 with white sweet clover at the rate of 10 lbs. per acre, with 1 bu. oats as nurse crop. Sweet clover seed mixed with the oats.

May 8. Seeded Plot 2 with yellow sweet clover without nurse crop. Seed drilled in with alfalfa seeder.

May 8. Seeded Plot 3 at rate of 8 lbs. white sweet clover per acre with 1 bu. oats. Seeds mixed before sowing.

June 22. Plots given first irrigation.

July 26. Plots given second irrigation.

Oats on Plot 1 cut for hay. Practically no stand of sweet clover on Plot 2.

Aug. 10. Harvested oats on Plot 3. A yield of 785 pounds of threshed grain on the half-acre. There was also an excellent stand of sweet clover on this plot.

Plots 1 and 2 were plowed in the fall to be reseeded to sweet clover in the spring of 1915.

The Plots 1 and 2 were worked down and seeded in the spring of 1915 at the same rate as the preceding year but no stand was obtained.

The results obtained from these experiments would seem to indicate that sweet clover will not do as well on well prepared soil as on that less well prepared. Packing seems to be the most essential thing.

Plots 1 and 2 were looser and were plowed deeper as they had been in grains for two years preceding the sweet clover sowing. Plot 3 had been in alfalfa and the soil was much more compact so that such deep plowing was impossible and the seed bed was more easily compacted. Even fall plowing on Plots 1 and 2 did not compact the soil sufficiently to get a good stand.

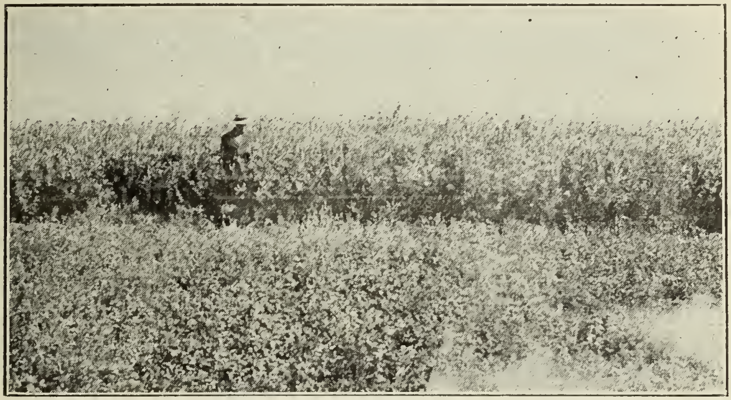


Fig. 3—Sweet clover on cultivated land, showing first and second growths.

In 1915 Plot 3 gave a yield of 2930 pounds of cured hay from a measured one-half acre. Only one cutting was made. This cutting was made on July 20. It should have been made two weeks earlier as the clover when cut was rather coarse for hay. Had the first cutting been made at the earlier date two cuttings could easily have been obtained. As it was, a good second growth was made. A strip left after cutting the measured area in July was allowed to stand for seed. It grew very tall, but on account of cool weather and rain did not mature seed before frost. The first and second growths are shown in Figure 3.

II. How to Grow Sweet Clover.

In order to be successful in growing this crop one must have some understanding of the habits and requirements of the plant. With this knowledge one need not

fail in growing the crop nor fear that it will become a troublesome weed. The main essentials to be observed in order to obtain a successful stand of sweet clover are the preparation of the seed bed and the selection of the seed.

Preparation of the Seed Bed.

To have the seed bed well packed is the essential thing. Experiments have shown and reports from farmers in various parts of the state indicate that success is rarely attained when the seed is sowed on new plowing and on well worked soil. A seed bed that is hard below with just enough loose soil on top to cover the seed is best. If there is sufficient moisture seed may be sowed broadcast on the sod and lightly disked in enough to cover it. Sweet clover seed has strong viability and will often lie in the ground a year or two before germinating. It takes considerable time for moisture to penetrate the hard seed coats. Alternate freezing and thawing is often sufficient to give the seed the needed covering of soil. This is evidenced by the fact that sweet clover grows well on the hard roadways, embankments, etc. There is more danger of having the seed bed too loose than too hard when trying to grow sweet clover on cultivated land. In preparing land for sweet clover seeding, such tools should be used as will only work the surface very lightly.

Methods of Seeding.

Sweet clover seeds itself by shattering from the plants and lying on the ground through the winter. Thus it would seem that the seed could as well be sown in the fall. This has been done successfully in parts of the state. The sweet clover was broadcasted after winter wheat was sowed. The time of sowing does not matter so much if the seed gets moisture. Seeding may be done from January until June. Much of the seed will not germinate until the next year anyway. Farmers in the eastern part of the state report sowing the seed during the winter on the snow and letting it sink into the ground. This can be done if winds are not too severe.

Selection of seed is important. Sweet clover seed is often gathered in waste places and therefore contains certain weed seeds. Care should be taken that only good clean seed is used. Hulled and unhulled seed may be obtained upon the market. It does not make much difference which is used. The unhulled is more apt to contain impurities. On the other hand the hulls on the seed may help to gather moisture and thus help germination. Ten pounds of good clean seed is sufficient for sowing one acre under irrigated conditions. One-half this amount is sufficient for the dry farm. More of the unhulled seed should be used. The seed may be drilled or broadcasted. If drilled care should be taken not to cover it too deep. Sweet clover should never be covered to a depth of more than half an inch. Inoculation of either the soil or the seed is not necessary in Wyoming. See Figure 4.

Treatment of Hard Seeds.

Many of the seeds in sweet clover have hard seed coats which are difficult for moisture to penetrate. Therefore some of the seeds are very slow in germinating, many in fact not germinating until the following year after sowing. Various methods of treating the seeds to soften the seed coats have been devised with more or less success. It is doubtful however, if any of the methods will be widely adopted by the farmers, as most of the seeds will germinate the second year anyway.

The sulphuric acid treatment probably gives the best and quickest results. This method consists in pouring concentrated sulphuric acid over the seed and stirring for twenty minutes. The seed is then placed under running water and washed until the acid is thoroughly washed out. The seed is then dried and planted. Porcelain or enameled ware should be used as the acid corrodes any

other substance. Care should also be taken that the acid does not come in contact with the hands or clothing. Seed given this treatment in field experiments of the Station made a much thicker stand the first year after seeding than the untreated seed, but no difference could be observed in the field the second year.

Fig. 4—Pot cultures to show effect of seed treatment. IA.—Untreated seed. IIA.—Inoculated seed (Nitragin). IIIA.—Seed treated with concentrated sulphuric acid. IVA.—Seed coats scarified.

The Iowa State College has a scarifying machine which makes the seed coats thinner by rubbing them over sand paper. A pound of seed was sent there for treatment and used in comparison with the sulphuric acid treated and untreated seed. This showed a marked increase in germination over the untreated seed but not so good as the seed treated with sulphuric acid. The scarifying machine will probably not be practicable for the average farmer, but would be practicable for the seed house or dealer. Scarified seed could be put on the market at a slightly advanced price.

The results of germination tests are shown in the following table:

Germination Tests of Sweet Clover.

No.	100 Seeds Each	Number of Seeds Germinated				
		In 1 day	In 2 days	In 4 days	In 6 days	Total Per Cent
1.	Untreated Seed	13	45	48	48	48
2.	Scarified	42	74	78	78	78
3.	Acid Treatment	82	87	89	89	89

No. 1. Untreated seed. Just as it came from the dealer.

No. 2. Scarified seed. Treated in scarifying machine at Iowa State College.

No. 3. Treated with concentrated sulphuric acid.

In the pot tests shown in Figure 4 there was apparently no increase in the germination of the scarified seed over the untreated seed. A marked difference is shown, however, in the acid treated seed. The even and dense growth shows the early germination. Apparently, however, the only advantage gained in the treatment of sweet clover seed is the hastening of germination.

III. The Products of Sweet Clover.

Sweet Clover for Hay.

Sweet clover when cut at the right time and cured properly makes good hay. All of the sweet clover raised at the agronomy farm the past five years has been used for this purpose. It has usually been stacked near the corral and fed to the horses when they were running out. The 1915 crop was taken to the stock farm and used in a feeding experiment.

Sweet clover for hay should be cut before the stems begin to get woody. Just before blossoming begins is about the right time. It cures slowly. At the station the plan has been to rake into windrows about a half a day after cutting, and put up in shocks. It is allowed to cure in the shock. The curing takes about four or five days of good weather, about the same as alfalfa cured in this way. By this method few of the leaves are lost. If salt is sprinkled on when put in the stack the quality is improved and stock eat it better.

Sweet Clover for Pasture.

A number of farmers have reported good results from using sweet clover for pasture. It has proven better than alfalfa for this purpose in dry farm sections and very little trouble from bloat has been reported. It should not be pastured too close and some new seed should be scattered over the ground every year so that the pasture will be permanent. So far, the Wyoming station has conducted no experiment to test the pasture value of sweet clover.

Sweet Clover for Seed.

In many parts of the state sweet clover produces an abundant seed crop, and saving the seed is profitable, as the market demand for it is good. If seed is harvested from waste places where a mower or binder cannot be used, the plants can be cut by hand or with a scythe and tied up in bundles. These when cured can be threshed. Sweet clover should be cut for seed when most of the heads have turned dark. A binder may be used in larger fields and the bundles shocked like small grain. The seed shatters badly when dry; therefore the bundles must be handled carefully. It is better, if possible, to harvest it when slightly damp. It must be thoroughly dry, however, when threshed.

CONCLUSIONS.

There is no doubt but that sweet clover is a good crop for Wyoming conditions. The following points may be stated in its favor:

It prepares heavy, hard and poor soils for the growing of alfalfa.

It is a good fertilizer, adding both nitrogen and humus to the soil, when plowed under as green manure.

It has a high feeding value. Analyses show that it has nearly as much protein and more fat than alfalfa.

It will grow on land too wet or too dry for alfalfa.

It is more alkali-resistant than alfalfa.

It can be grown successfully under irrigation or on the dry farm.

It seeds freely under both of the above conditions.

It makes an excellent pasture and a first class green manure.

It does best on soils that contain plenty of lime.

It is a weed in waste places only. It never damages cultivated crops.

Those desiring a more extended discussion of the varieties and history of sweet clover are referred to Farmers' Bulletin 485 by the Department of Agriculture, Washington, D. C.

BULLETIN NO. 111 DECEMBER, 1916

UNIVERSITY OF WYOMING

AGRICULTURAL EXPERIMENT STATION

LARAMIE, WYOMING

ALFALFA IN WYOMING

By T. S. Parsons

Bulletins will be sent free upon request
Address: Director Experiment Station, Laramie, Wyoming

UNIVERSITY OF WYOMING
Agricultural Experiment Station
LARAMIE

Alfalfa in Wyoming

BY T. S. PARSONS.

INTRODUCTION.

Alfalfa is pre-eminently the great forage crop of the semi-arid regions. The crop is now so well known in all parts of the country that any discussion of its history is unnecessary here. It is grown in all parts of the United States, and the acreage is rapidly increasing. In 1899 the United States had a total of 2,094,011 acres in alfalfa. In 1912 this had increased to 4,707,136 acres, or an increase of over 100 per cent in 15 years.

The increase in acreage in Wyoming has probably been proportionately as great, as the crop does exceptionally well under Wyoming conditions where water is available for irrigation, and with the development of hardier and more drought-resistant varieties, it is becoming increasingly important on the dry farm.

Permanent and prosperous farming demands the growing and feeding of some legume. No other legume is as valuable or as well adapted to the climatic conditions of the state as alfalfa. No other legume, with the possible exception of field peas and sweet clover, possesses like qualities of resistance to drought and cold, and yield. Being a hardy perennial, maintaining itself for several years when once established, and producing a heavy growth of forage high in protein makes alfalfa the greatest of all forage crops for Wyoming conditions. It not only furnishes an abundance of forage, but is a soil builder of the highest order. Two cuttings per year may be obtained in all parts of the state under irrigation and in the more favored sections three crops are obtained, with a considerable growth

of pasture. By the growing of alfalfa the lands of Wyoming can be made to produce double. Conditions here are much the same as they were years ago in Colorado and Utah. Not until the fields of these states were made fertile by alfalfa could potatoes, melons, and apples be profitably produced.

Alfalfa is a good crop for improving and maintaining the fertility of the soil, provided the crop is fed on the farm and the manure properly conserved and returned to the soil with such other materials as may be required. Since alfalfa is classed as a nitrogen gatherer and a soil builder, many erroneous ideas concerning the plant have arisen. It is not a crop adapted to poor land. Under proper conditions it gets a part of its nitrogen from the air and by means of the bacteria on its roots stores some of it up in the soil. If, however, the soil is not well supplied with humus, so that conditions are favorable to the development of bacteria, the alfalfa will use up the nitrogen as well as the other plant foods in the soil.

Examinations of the roots of alfalfa plants growing in soils on the Experiment Station farm, low in humus, have shown the nitrogen nodules to be absent, while those plants growing on soils well supplied with humus had a plentiful supply of nodules on the roots.

I. Choosing the Seed.

Alfalfa Varieties.

The botanical name of alfalfa is *Medicago sativa* L. All the different varieties, or strains, have originated from this, and are only distinct from this and from each other so far as habits of growth, hardiness, and productivity are concerned. Nine varieties have been grown at the Wyoming Station during the past six years, in order to study these variations. Some of these varieties show contrasts of decidedly practical value, such as hardiness, habits of stooling, resistance to frost, drought and diseases, and leafy hay qualities, *i. e.*, the proportion of leaves to stems in the hay. The names of these varieties and the yields for five years are given in Table I.

TABLE I—*Five Years' Experiments With Alfalfa Varieties at the Wyoming Station, 1911-1915*

VARIETY	Yield 1/5 A. 1911			Yield 1/5 A. 1912			Yield 1/5 A. 1913			Yield 1/5 A. 1914			Yield 1/5 A. 1915			Av. yield per acre, 5 years	Av. weight 10 green plants
	First crop	Second crop	Yield per acre	First crop	Second crop	Yield per acre	First crop	Second crop	Yield per acre	First crop	Second crop	Yield per acre	First crop	Second crop	Yield per acre		
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	tons	ozs.
Turkestan	1090	1050	10700	1180	1070	11250	525	735	6300	660	600	6300	550	435	4925	3.90	30
Sand Lucern	1100	1050	10750	1135	1100	11175	760	850	8050	700	690	6950	500	520	5100	3.67	28
Grimm	1150	1100	11250	1185	1110	11475	1080	1140	11100	1180	900	10400	900	750	8250	5.25	48
Provence France	800	750	7750	900	800	8500	560	670	6150	630	520	5750	540	450	4950	3.31	48
Utah Seed	650	525	5875	640	510	5750	580	650	6150	680	580	6300	630	770	7000	3.10	24
German Seed	1045	950	9975	1040	975	10075	510	630	5700	670	510	5900	700	780	7400	3.90	24
Dry Grown Seed	620	525	5725	640	500	5700	945	980	9625	910	850	8800	640	450	5450	3.53	32
Montana Seed	1275	1120	11975	1250	1050	11500	770	860	8150	920	840	8800	540	510	5250	4.56	26
Native Seed (one-fourth acre)	......	......	......	1260	1150	9640	1190	1240	9720	1325	1200	10100	900	550	5800	4.38	36

A study of the table shows the Grimm to be considerably in the lead. There are reasons for this. It will be noticed that the Turkestan, Sand Lucern, Grimm, and Montana varieties stood nearly the same for the first two years. The winter of 1912-13 was very severe on alfalfa, and all of the varieties except the Grimm were winterkilled in varying degrees. This hardy variety showed no winterkilling at all and has proved perfectly hardy ever since. The yield of 1915 was lowered by late spring frosts, affecting the first cutting. The dry-grown seed had its conditions changed by irrigation, therefore the comparison in this test is hardly fair. The above yields are reckoned on the basis of one-fifth acre plots. Twenty-six other varieties from the United States Department of Agriculture were grown in rows, while native seed has been sowed each year in comparatively large fields and under varying conditions to determine the best time of seeding, the best amount of seed to sow, and the best kind of preparation of the seed bed, and also to study the methods of caring for and harvesting the crop and methods for the successful production of seed.

Alfalfa Types.

Questions often asked are: "Why does one variety of alfalfa stand through the winter better than another?" "Why does one variety yield more per acre?" and "Why is the Grimm better than the other varieties?" The preceding table shows the Grimm to have averaged 0.69 tons per acre more than the best of the other varieties, and it has showed no winterkilling. Therefore, the question arises, Has the type of the plant anything to do with its hardiness? Probably it has. Another question also is often asked: "Is the Grimm of sufficiently higher value to pay the advanced price asked for its seed?" Probably not, provided the farmer can get good northern-grown alfalfa seed at a reasonable price.

The study of types, however, is an important one. The farmer is interested in the one that will make the most hay. Will the Grimm do this? Results show that it does, on ac-

count of its resistance to winterkilling. If there were the same number of plants per acre it would not yield better than some of the other varieties, but usually more of the plants of the Grimm stand from year to year. It has not, however, a great advantage if the cost of seed and the yield per acre are compared. At the Colorado Station the Baltic variety outyielded the Grimm, while the Liscom is recommended by Montana growers. These two varieties are much like the Grimm in character and habits of growth. They are undoubtedly of the same origin as the Grimm, both having come from Minnesota, where the Grimm variety originated.

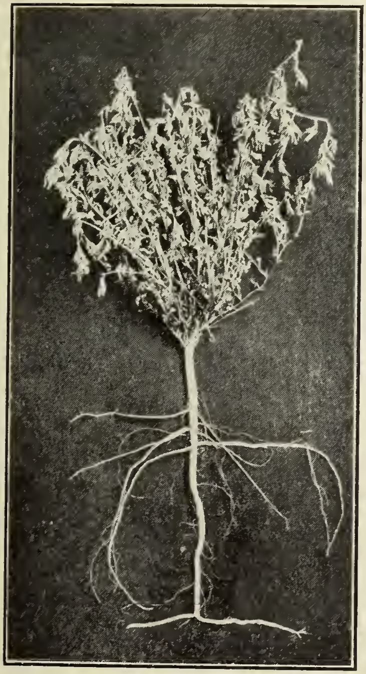


Fig. 1—One-year-old Grimm Alfalfa

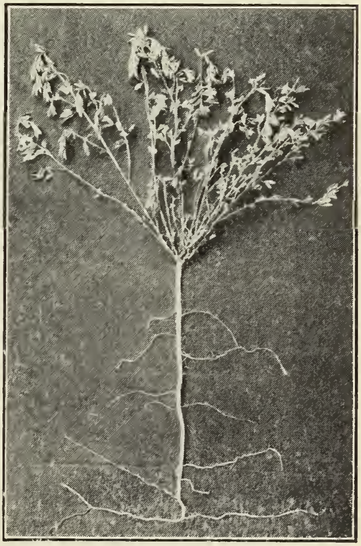


Fig. 2—One-year-old Common Alfalfa

The habits of the Grimm, however, commend it to favor. Its heavy stooling habit produces finer stems and a more leafy hay. The underground shoots and feeding roots make it very hardy and resistant to winterkilling and late spring frosts. A study of the cuts (Figs. 1 and 2) of the one-year-old plants of the Grimm and the common variety shows this habit of growth in the Grimm plant, and its heavy root system as compared with the other. The Grimm is undoubtedly the best for dry-farm conditions. Less seed of this variety is required per acre and it is a heavy seed producer. Even at the high price of the Grimm seed at the present time, it would undoubtedly pay the farmer to sow a small amount and produce seed for the planting of larger areas.

Choice of Variety.

There are so many varieties and strains advertised at the present time that the farmer is at a loss to know which one to plant. The fancy varieties are so high priced that they are almost out of the question for general use. There are certain factors that should be kept in mind when selecting alfalfa seed:

The native-grown seed will be better for local conditions than fancy, imported seeds.

The farmer need not concern himself seriously in the choice of seed further than to try to get that which is locally grown.

If he cannot do this, he should get good, viable, and pure northern-grown seed. The native Wyoming, Montana, or Dakota seed is well adapted to Wyoming conditions and will do as well or better than many of the highly advertised fancy strains. If one desires to try the Grimm or some of the other varieties, he can do so on a small scale and at not too great expense.

In buying one should be certain as to the source of the seed and under no circumstances buy southern-grown seed.

Seed should be purchased from guaranteed sample and the sample should be sent to the Seed Commissioner for test

as to purity and germination. The Dairy, Food and Oil Department at Cheyenne maintains a seed-testing department, where the testing is done free of charge by the State Agronomist. Every farmer should avail himself of this service, especially where purchasing alfalfa seed. Alfalfa seed should be plump, of good, bright color, and entirely free from weed seeds.

Fig. 3—Grimm Alfalfa

The Wyoming Seed Law.

Since the adoption of the state pure seed law the quality of the alfalfa seed sold within the state has been greatly improved. Outside dealers no longer ship low-grade alfalfa seed into the state. The law of Wyoming requires that alfalfa seed shall pass a purity test of 96 per cent and a germination test of 85 per cent and must be entirely free from the seed of dodder and other noxious weeds. Alfalfa seed that is not up to this standard cannot be offered for sale in the state.

The large seed houses and dealers have complied readily with the law, but many farmers are still careless in purchasing and selling seed among themselves. From March 1 to May 1, 1915, one hundred and thirty samples of alfalfa seed were tested by the State Agronomist. Many of these were of low grade, but were comparatively free from weed seeds, so that most of them were passed. The season of 1915 was unfavorable to the production of alfalfa seed. Therefore, much inferior seed was offered for the spring sowing of 1916. All alfalfa seed should be thoroughly cleaned and graded before being offered for sale.

II. Alfalfa Experiments at the Wyoming Station, 1911-1915.

The writer took charge of the agronomy work at the Wyoming Experiment Station on March 1, 1910. At that time the varieties listed in Table I were growing in quarter-acre subdivisions of Plots 30 and 31, having been seeded under the supervision of Mr. L. B. McWethy, who was then the Station Agronomist. The varieties on Plot 30 were, Turkestan, Sand Lucern, Grimm, and Provence France; and those on Plot 31 were, Utah Seed, German Seed, Dry Grown Seed, Montana Seed, and Native Seed. The crowding of other work and unfavorable conditions, such as lack of irrigation water and a severe freeze in August, so hindered the work of 1910 that the results of that year are not included in this bulletin. The work was better in hand by 1911, and so the experiments here discussed begin with that year.

A field of 15 acres at the south end of the farm was also in alfalfa. Much of this field needs leveling and the lower parts are affected with alkali, so that the stand is somewhat thin. A part of this field has been broken up and reseeded, and new areas have been seeded each year.

Alfalfa Work in 1911.

The crop of 1911 was a great improvement over that of 1910. The first crop was injured to some extent by improper

irrigation, but the second crop came on well, so that the total yield for the year was good. There was no winterkilling in any of the varieties and but little difference in the yields of the several varieties. (See Table I.) This year the alfalfa renovator was used for the first time to the great improvement of the crop. The benefits of renovating were most apparent in the south field, where there was a good deal of foxtail and other weeds in the alfalfa. All of the alfalfa received two irrigations during the season—one after growth had started in the spring and one after the first cutting.

Work on Plots.
- April 25. Plots renovated.
- May 27. Crop growing well. Plants not noticeably affected by spring frosts. Height 6 inches at this date.
- June 6-7. Plots given first irrigation.
- July 5. Plants about one-half in bloom.
- July 8. First cutting. Hay cured in shock 4 days.
- July 17-25. Plots given second irrigation.
- Aug. 1. First bloom on second crop.
- Aug. 22. Second cutting. Cured 4 days in shock.

At the time these plots were sowed in 1909, duplicate plots were sowed. These were not uniform nor good yielders on account of having been used for an experiment to determine the best time of sowing the seed after plowing. These plots were broken up in the fall of 1911 to be used for other purposes.

Alfalfa Work in 1912.

In the spring of 1912 some cooperative work in testing of varieties was taken up with the United States Department of Agriculture. Twelve samples of seed were received for this purpose and these were sowed on the part of the agronomy farm known as Field A, on Plot 18.

In some cases there was sufficient seed to plant one drill width across the plot and in other cases there was only sufficient seed to plant one row. Table II gives a list of the varieties sowed and their departmental numbers and time of seeding.

Fig. 4—Grimm Alfalfa on left; Ordinary on right. Note weeds on right, showing alfalfa winter-killed

Table II—*Showing Date of Seeding of Alfalfa Varieties Planted in Rows, 1912.*

No.	Name	S. P. I. No.	Date planted	Remarks
1	Sand Lucern	23481	May 20	Plowed up in 1913
2	Turkestan	24352	May 20	
3	Turkestan	23203	May 20	
4	Corn Alfalfa	29212	May 20	
5	North Grown	32279	May 25	Kept with other varieties for seed
6	Turkestan	21032	May 25	
7	Grimm	29987	May 25	
8	Turkestan	22788	May 25	
9	Turkestan	22790	May 25	
10	*Medicago falcata*	30436	May 25	
11	*Medicago falcata*	30009	May 25	
12	*Medicago falcata*	28071	May 25	
13	*Medicago falcata*	31703	May 25	

The first four varieties in Table II did not make a good stand, the seed being of poor quality, therefore they were plowed up in 1913, in order that the land might be used for other variety tests.

The seed was slow in coming up, the season being rather dry, and it was not desirable to irrigate until late. The varieties planted in rows were cultivated and all the varieties were given one irrigation during the season.

The varieties showed a great deal of variation in height, stooling habits, color of bloom, etc. All of the varieties bloomed quite freely, but only a few of them produced seed, the blossoms appearing to blight when about in full bloom. All of the new seeding, except the first four numbers, entered the winter in good condition.

Work in Variety Plots, 1912.

The quarter-acre variety plots came through the winter with apparently no winterkilling. The late spring frosts, however, retarded the growth of the first cutting somewhat. The following is the record of the work for the year:

PLOT 30.

March 28. Renovated the plots.

June 8. Alfalfa varieties growing slowly on account of cool weather.

June 17. Season late and growth of all varieties except Grimm retarded by frosts. Plots given first irrigation.

June 22. All varieties growing rapidly since irrigation.

June 8. Alfalfa beginning to bloom. Height of Provence France, 2 ft. 4 in., about 4 in. taller than other varieties.

July 16. Grimm and Sand Lucern one-third in bloom. Height, 2 ft. 2 in.

July 20. Cut Grimm and Sand Lucern, height 30 in.

July 21. Turkestan in half bloom and Provence France one-third in bloom.

July 22. Cut Provence France and Turkestan. Height of former, 30 in. Height of latter, 25 in.

All varieties were raked soon after cutting, with side delivery rake, and cured in the shock. (For yields, see Table I.)

Aug. 13. Weather favorable and all the alfalfa varieties are growing rapidly.

Aug. 22. Plots given second irrigation.

Sept. 5. Cut second crop. Hay cured in shock. (For yields, see Table I.)

PLOT 31.

March 28. Renovated the plots.

June 5. Alfalfa varieties all growing slowly on account of cold weather.

June 17. Varieties all affected by frost.

Plots given first irrigation.

June 28. All varieties growing rapidly.

June 8. Montana and Dry Grown seed 5 in. higher than German and Utah seed. Height of former 24 in. Height of latter, 19 in.

July 12. Dry Grown and German seed beginning to bloom.

July 16. Montana seed beginning to bloom.

July 21. Varieties about one-half in bloom.

July 22. Cut Dry Grown, German and Utah seed.

July 23. Cut Montana seed.

All plots raked green with side delivery rake and cured in shock.

(For yields, see Table I.)

Alfalfa Work, 1913.

The winter of 1912-1913 was very severe on winter grains and alfalfa. Much winterkilling was reported from all parts of the state. At the Station most of the plot varieties showed various degrees of winterkilling; the Grimm being the only variety that appeared to be absolutely hardy and resistant to winterkilling.

In 1911 seeding of government varieties on Plot 18 came through the winter with some loss. The remaining plants, however, made good growth and produced a fair crop for new seeding. The varieties were mowed July 30. No record of yields was kept. The plots were irrigated immediately after the first cutting. The varieties were not cut the second time, being allowed to grow through the balance of the season. At the time of killing frosts, September 12, the varieties averaged about 12 inches in height and were just beginning to bloom.

PLOT 30.

March 29. Renovated the plots.

May 3. Alfalfa just starting to grow.

May 23. Irrigated the plots.

June 4. All of the varieties growing very rapidly.

June 28. Grimm beginning to bloom.

June 29. Sand Lucern beginning to bloom.

July 1. Turkestan beginning to bloom.

July 2. Provence France beginning to bloom.

July 3. Plot given second irrigation.

July 8. Provence France 29 in. high, and one-third in bloom. Grimm 28 in. high, and one-half in bloom. Turkestan 27 in. high, and one-fourth in bloom.

July 10. Cut all varieties, raked with side delivery rake and cured it in shock.

(For yields, see Table I.)

Yields of all varieties except Grimm lighter this year on account of winter killing.

July 24. Heavy rain fell, causing rapid growth of alfalfa.
Aug. 5. Plots given third irrigation. ,
Second crop apparently coming on better than first crop.
Aug. 12. Turkestan beginning to bloom.
Aug. 14. Sand Lucern beginning to bloom.
Aug. 15. Grimm beginning to bloom.
Aug. 29. Second cutting cured same as first crop. (For yields, see Table I.)

PLOT 31.

March 29. Renovated the plots.
May 3. Alfalfa varieties just starting to grow.
May 25. Plots given first irrigation.
June 4. All varieties growing rapidly. No injury from spring frosts this year.
July 9. Montana seed 28 in. high and one-fourth in bloom.
Dry Grown seed 31 in. high and one-half in bloom.
German seed 25 in. high and one-half in bloom.
Utah seed 28 in. high and one-half in bloom.
July 10. Cut all varieties. Raked with side delivery and cured in shock.
(For yields, see Table I.)
July 24. Heavy rain on this date, causing alfalfa to grow rapidly.
Aug. 6. Plots given third irrigation.
Aug. 9. All varieties appear better than before first cutting.
Aug. 15. Montana seed beginning to bloom.
Aug. 17. German seed beginning to bloom.
Aug. 18. Utah seed beginning to bloom.
Aug. 19. Dry Grown seed beginning to bloom.
Aug. 29. Cut all varieties and cured as Plot 30.
(For yield, see Table I.)

Alfalfa Work, 1914.

Varieties from the United States Department of Agriculture left from last year stood winter well. These and the row varieties were given no irrigation during the season. The plants were allowed to stand until seed was matured.

PLOT 30.

May 26. Alfalfa varieties all growing rapidly; no injury from spring frost.
June 6. Plot given first irrigation.
June 26. First blossoms appearing. Turkestan 28 in. high. Sand Lucern 33 in. high. Grimm 29 in. high. Provence France 28 in. high.
July 6. Cut all varieties. Turkestan one-fourth in bloom. Sand Lucern one-third in bloom. Grimm one-half in bloom. Provence France one-fourth in bloom.
(For yield, see Table I.)
Weight of ten individual plants at second cutting: Turkestan, 48 oz.; one-fourth winterkilled. Sand Lucern, 28 oz.; one-third winterkilled. Grimm, 48 oz.; perfect stand. Provence France, 30 oz.; one-fourth winterkilled.

The winterkilling was the result of the cold winter of 1912 and 1913. There was apparently no winterkilling in the winter of 1913 and 1914.

July 20. Plots given second irrigation.

Aug. 6. Blossoming for second crop.

Aug. 13. Turkestan one-eighth in bloom; height 23 in. Sand Lucern one-sixth in bloom; height 24 in. Grimm one-fourth in bloom; height 25 in. Provence France one-sixth in bloom; height 25 in.

Aug. 15. Made second cutting. This was unusually early for the second cutting, but the season was very favorable and growth rapid.

(For yield, see Table I.)

Sept. 2. Third growth, 4 in. high.

Sept. 12. First killing frost. Alfalfa then 14 in. high. Usually there is but little growth after the second cutting.

PLOT 31.

May 20. Reseeded bare places in plots.

May 25. Alfalfas all growing very rapidly; no injury from spring frosts.

June 27. First blossoms appearing.

July 6. Mowed the plot. Utah seed one-fourth in bloom, 27 in. high. German seed one-fourth in bloom and 26 in. high. Dry Grown seed one-third in bloom and 27 in. high. Montana seed one-third in bloom and 25 in. high.

Weight of 10 green plants at second cutting: Utah seed, 26 oz.; one-third winterkilled. German seed, 32 oz.; one-fourth winterkilled. Dry Grown seed, 24 oz.; one-fifth winterkilled. Montana seed, 24 oz.; one-sixth winterkilled.

July 21. Plots given second irrigation.

Aug. 3. Blossoms appearing for second crop.

Aug. 14. Utah seed one-sixth in bloom and 24 in. high. German seed one-fourth in bloom and 24 in. high. Dry Grown seed one-fourth in bloom and 25 in. high. Montana seed one-sixth in bloom and 24 in. high.

Aug. 15. Second cutting.

(For yields, see Table I.)

Sept. 12. Killing frost. Third crop 14 in. high.

New Alfalfa Seeding, 1914.

Some new areas were seeded to alfalfa in 1914 to test various methods of sowing, namely, sowing with and without a nurse crop and on fall and spring plowing.

On May 25, one-quarter of an acre on Plot 32 was sowed to alfalfa alone at the rate of 10 pounds of seed per acre. Another quarter acre on the same plot was sowed to alfalfa at the same rate with oats as a nurse crop. The land was spring plowed. The alfalfa sowed alone was broadcasted and harrowed in, while that with the nurse crop was drilled. An ex-

cellent stand was obtained from the seed sowed alone, but no stand was obtained from that sowed with the nurse crop. There is danger in drilling alfalfa of getting it covered too deeply when sowed with a nurse crop. This is especially true when sowing in spring plowing.

On Field B an area of four acres was plowed in the fall of 1912, and summer-fallowed in the summer of 1913 to prepare it for alfalfa. These acre plots were worked with the spike-tooth and acme harrows from April 18 to May 7, to prepare a good seed bed. Plots 2 and 4 were seeded to oats at the rate of one bushel per acre, as a nurse crop for the alfalfa. The alfalfa was sowed on May 11 with an alfalfa drill at the rate of 10 pounds per acre; Plots 1 and 3 being seeded to alfalfa without a nurse crop.

RECORD OF TREATMENT, NEW SEEDING.

May 20. Alfalfa coming up on all the plots.

July 2-6. Plots given first irrigation.

July 10. Alfalfa growing rapidly.

July 16. Mowed weeds on Plots 1 and 3.

July 20. Alfalfa sowed without nurse crops appears to be a thicker stand, but that sowed with nurse crop grew taller, probably on account of the shading by the nurse crop.

July 25-27. Plots given second irrigation.

July 30. Mowed nurse crop on Plots 2 and 4.

Aug. 18. Mowed all pots and allowed material to remain on the ground as a mulch.

At the close of the season there was apparently no difference in the stand of the alfalfa sowed with the nurse crop and that sowed without. It would appear that the preparation of the seed bed, the moisture supply, and the seed are more important factors in the growth of the crop than the nurse crop. The nurse crop, however, gives a considerable crop of hay which otherwise could not be obtained from the alfalfa ground the first season.

Alfalfa Work, 1915.

PLOTS 30 AND 31.

Plots received a top dressing of three tons of barnyard manure during the winter of 1914-1915.

May 18. Plots renovated with the alfalfa cultivator. This implement had not been used before. Apparently good results may be obtained from its use.

May 25. Plots given first irrigation.
July 19. First cutting. Hay cured in shock.
(For yields, see Table I.)
Aug. 3. Plots given second irrigation.
Sept. 7. Second cutting. (For yields, see Table I.)

The season was cold and backward. The growth of the varieties was checked all through the season. The first cutting was very poor and the second cutting below the average.

New Seeding.

Plots on Field B seeded in 1914 came through the winter with no winterkilling. A good stand remained on all the plots, but yields were below the average on account of poor season. Yield of four acres, two cuttings, 2.22 tons per acre.

A larger area in Field C was sown to alfalfa with oats as the nurse crop in 1915. This land is rather low and a portion of it receives seepage water. A total of about 12 acres was sowed. The area was divided into three sections, one section being sowed to oats and alfalfa drilled in at the same time. One section was sowed to oats and the alfalfa broadcasted and harrowed in, and one section was seeded to oats and alfalfa, with the broadcast alfalfa seeder. The ground was so wet that it was impossible to cut the oats. There was apparently a good stand of alfalfa in the fall, but that on the low part of the field was killed. There was no apparent difference in the stands obtained by the different methods of seeding. In each case 10 pounds of alfalfa seed was sowed to the acre, with one bushel of oats per acre as a nurse crop.

The broadcast seeding of alfalfa alone in 1914, on Plot 32, gave a yield of 2.75 tons per acre in 1915. Results this year would seem to indicate that alfalfa can be grown just as well with a nurse crop if there is sufficient moisture, and that broadcasting is as good as drilling.

Native Seed.

In the spring of 1912 two small areas consisting of one-half acre each were seeded with Wyoming-grown alfalfa seed to compare the effect of previous crops. One plot had been

in grain the previous year and the other in field peas. The plots were given the same treatment and were seeded at the same time with the same variety of seed. An excellent stand was obtained in the plot that had been in peas, but only a poor stand was obtained in the plot that had been in grain.

While peas will not inoculate for alfalfa, they seem to put the soil in better physical condition. In plowing and harrowing, the pea ground was more friable than the grain ground, so that a better seed bed was formed. There is no doubt but that field peas will help to put land that is in poor condition in better condition for alfalfa. The poor stand on the grain ground was plowed up the following year, but that on the pea ground was allowed to stand. One noticeable fact in regard to the native seed is that it has not winterkilled to any extent. This is peculiar since its first winter was unusually severe. (For yields, see Table I.)

TABLE III—*Showing Six Years' Records of the Date of Bloom and Time of Cutting of the Alfalfa Varieties in the Experimental Plots at Laramie, Wyoming.*

VARIETY	Beginning of Bloom									
	First Cutting					Second Cutting				
	1911	1912	1913	1914	1915	1911	1912	1913	1914	1915
Turkestan	July 9	July 16	July 1	Jun. 28	July 18	Aug. 18	Aug. 26	**Aug. 12**	Aug. 5	Aug. 28
Sand Lucern	**July 4**	**July 8**	Jun. 29	Jun. 26	**July 10**	Aug. 16	Aug. 24	Aug. 14	**Aug. 4**	Aug. 27
Grimm	**July 4**	**July 8**	**Jun. 28**	**Jun. 25**	**July 10**	Aug. 16	Aug. 25	Aug. 15	**Aug. 4**	Aug. 27
Provence France	July 9	July 10	July 2	Jun. 29	July 12	Aug. 18	Aug. 27	Aug. 18	Aug. 5	Aug. 29
Utah Seed	July 5	July 12	July 3	Jun. 27	July 14	Aug. 15	Aug. 27	Aug. 18	Aug. 7	Sept. 1
German Seed	**July 4**	July 12	July 3	Jun. 30	July 14	**Aug. 14**	Aug. 25	Aug. 17	Aug. 5	**Aug. 25**
Dry-Grown Seed	July 6	July 12	July 4	Jun. 30	July 13	**Aug. 14**	Aug. 25	Aug. 19	Aug. 7	Aug. 26
Montana Seed	**July 4**	July 16	July 3	Jun. 27	**July 10**	**Aug. 14**	Aug. 27	Aug. 15	Aug. 5	**Aug. 25**
Native Seed	....	July 16	July 3	Jun. 27	July 12	....	**Aug. 17**	Aug. 15	Aug. 7	Aug. 26

TABLE III—(Continued).

VARIETY	Time of Cutting									
	First Cutting					Second Cutting				
	1911	1912	1913	1914	1915	1911	1912	1913	1914	1915
Turkestan	July 8	July 22	July 10	July 6	July 19	Aug. 22	Sept. 5	Aug. 29	Aug. 15	Sept. 7
Sand Lucern	July 8	July 20	July 10	July 6	July 19	Aug. 22	Sept. 5	Aug. 29	Aug. 15	Sept. 7
Grimm	July 8	July 20	July 10	July 6	July 19	Aug. 22	Sept. 5	Aug. 29	Aug. 15	Sept. 7
Provence France	July 8	July 22	July 10	July 6	July 19	Aug. 22	Sept. 5	Aug. 29	Aug. 15	Sept. 7
Utah Seed	July 8	July 22	July 10	July 6	July 19	Aug. 22	Sept. 7	Aug. 29	Aug. 15	Sept. 7
German Seed	July 8	July 22	July 10	July 6	July 19	Aug. 22	Sept. 7	Aug. 29	Aug. 15	Sept. 7
Dry-Grown Seed	July 8	July 22	July 10	July 6	July 19	Aug. 22	Sept. 7	Aug. 29	Aug. 15	Sept. 7
Montana Seed	July 8	July 25	July 10	July 6	July 19	Aug. 22	Sept. 7	Aug. 29	Aug. 15	Sept. 7
Native Seed	....	July 25	July 10	July 6	July 19	....	Sept. 7	Aug. 29	Aug. 15	Sept. 7

Varieties earliest to bloom (dates in bold face in table):

1911, first cutting: Sand Lucern, Grimm, German, Montana, July 4; second cutting: German, Dry Grown, Montana, Aug. 14.
1912, first cutting: Sand Lucern, Grimm, July 8; second cutting: Native, Aug. 17.
1913, first cutting: Grimm, June 28; second cutting: Turkestan, Aug. 12.
1914, first cutting: Grimm, June 25; second cutting: Sand Lucern, Grimm, Aug. 4.
1915, first cutting: Sand Lucern, Grimm, Montana, July 10; second cutting: German, Montana, Aug. 25.

Summary of Experiments at the Wyoming Station.

1. The Grimm leads all other varieties in hardiness, in earliness of maturity, and yield per acre. (See Tables II and III.)

2. Broadcasting gave as good results as drilling.

3. Equally good stands were obtained with and without the nurse crop.

4. Summer fallowing put the ground in the best condition for alfalfa.

5. When a nurse crop is used a crop of hay averaging one ton per acre was obtained the first year.

6. The experiments showed no advantage from inoculation.

7. Liming the soil of the agronomy farm is not necessary.

8. Ten pounds of seed to the acre gave a sufficiently heavy stand in all cases.

9. One irrigation for each cutting was usually sufficient.

10. A well-packed seed bed with a loose surface, good seed, and sufficient moisture in the ground to germinate the seed and start growth seem to be the essential factors for successful alfalfa growing under conditions similar to those at the agronomy farm.

III. Cultural Directions for Growing Alfalfa.

Inoculation.

Inoculation of either the seed or the soil for the growing of alfalfa has not been found necessary in Wyoming. There is little trouble in getting a good stand and a successful growth where good seed is planted at the proper time in a well-prepared seed bed. Some experiments in inoculation have been carried out at the Station, but in no case have there been any better results than where there was no inoculation. (See Fig. 5.) The field experiments gave no better results than the pot experiments.

Liming is also unnecessary in most Wyoming soils. Liming is often necessary in the soils of eastern or humid regions

on account of their tendency to become acid. Wyoming soils are not acid, but tend more toward alkalinity and are generally well supplied with lime; therefore, alfalfa does well. Experiments at this Station show that the addition of lime to the soil is of no benefit.

Fig. 5—Inoculation of Alfalfa.
1. Clear Alfalfa.
2. Inoculated Seed.
3. Soil Limed.
4. Soil Limed and Seed Inoculated.

Heavy manuring and a crop of white sweet clover will put the soil in good shape for growing alfalfa. The barnyard manure promotes the growth of bacteria in the soil and the bacteria on the roots of the sweet clover are closely related to those found on the roots of the alfalfa. There is seldom any trouble in getting a stand of alfalfa in soils well supplied with humus.

Selecting the Land.

Because of the wide distribution of alfalfa, its hardiness and deep-feeding roots, it is often taken for granted that the plant will do well on almost any kind of soil. This is a mistake. The selection of the field is of prime importance.

Alfalfa grows well on loamy soils. This condition can be obtained in almost any soil by the abundant use of manure. The character of the subsoil is also very important; there must be good drainage. This is why fields with considerable slope are better for alfalfa than low, level fields, where the water is

likely to stand. The water table should be not closer than 6 to 8 feet below the surface. Where the water table is closer than four feet it is doubtful if alfalfa will do well. If the subsoil is hard, impervious, or water-logged the feeding roots of the alfalfa cannot work to the best advantage. The subsoil must be loose enough so that the roots can penetrate it readily and get down to the moisture below. Even in a well-drained soil there may be saturation in the fall, so that the ground becomes covered with ice. Such a condition is almost sure death to alfalfa. When the plants are dormant they will stand flooding, but they will not stand being covered with ice. Alfalfa always does well on a hillside when once established, because water does not stand on the surface. The moisture conditions probably have more to do with the successful growing of alfalfa than any other factors. At the agronomy farm there has been no trouble in getting a stand of alfalfa, but it has been frequently observed that the plants have all been killed in the low spots in the fields where the water stood for a period of time. This was especially noticeable in the 1915 planting.

Alfalfa should not be seeded on new breaking nor on soils that have not been brought to good tilth by cultivation. Many letters of inquiry are received asking if alfalfa can be safely sown on new breaking or on sod that has merely been disked. The answer is invariably, "Do not risk it". At no time have such practices been successful at the Experiment Station. A few farmers have reported success from sowing alfalfa on breaking, but in practically all cases the breaking had been done the preceding summer or fall and the land thoroughly worked down in the spring before sowing, and there also chanced to be a good supply of moisture that season.

Alfalfa will not stand much alkali. Where the alkali spots are not too bad in an alfalfa field they can be neutralized by the use of barnyard manure. If this is not an effective remedy they can be sown to sweet clover. The clover is strongly resistant to alkali and makes good forage. The spots will look

better covered with a rich growth of sweet clover than when bare of vegetation.

Land as free of weeds as possible should be selected for alfalfa. For this reason land that has been summer-fallowed the previous season or that has been in a cultivated crop is best. Success will be practically certain wherever alfalfa is sowed on deeply plowed, fertile soil that has been summer-tilled for a season, or that has grown a cultivated crop. The soil should also have a good supply of moisture stored up in it at the time the seed is sowed.

Preparation of the Seed Bed.

Alfalfa when growing properly has a marvelous root development. To allow the proper development of this root system the land must be plowed to a good depth. The soil, however, must be well packed below the surface. Therefore, fall plowing is preferable to spring plowing, because the soil has time to become packed during the winter. The disking and harrowing in the spring puts the seed bed in excellent condition for the alfalfa seed.

Disking and harrowing of fall plowing should begin as soon as the ground can be worked in the spring, and should be kept up at frequent intervals until seeding time. The weed seed that is in the ground will germinate and the cultivation will kill it. Summer fallow of the previous year is the ideal seed bed for alfalfa. Such ground will be well packed and free from foreign seeds.

If land is plowed in the spring for alfalfa, much attention should be given to the packing of the same. The packer should be used, or if this implement is not available the disk harrow may be used, keeping the disks straight when running through the soil. If the field is rolled with a smooth roller to pack it, or if it is planked or floated, the spike-tooth harrow should be run over it at once to make a surface mulch and stop evaporation.

Where land is rather light and loose, merely disking the stubble is often sufficient to prepare it for the seeding of alfalfa. Such land, however, is likely to contain weed seeds; therefore, seeding alfalfa under these conditions is not advisable. Land that has been in some cultivated crop, like corn or potatoes the preceding year, need not be plowed. Disking and harrowing will put this ground into good condition for seeding to alfalfa, provided it is not weedy.

There should be a sufficient supply of moisture stored in the soil at planting time to germinate the seed and give the plants a good start. The seed should not be irrigated up if it can possibly be avoided. If very dry, it is better to irrigate the ground before seeding. Good drainage is also necessary.

Our uncultivated soils are generally lacking in humus. Humus is essential for the growth of bacteria and the bacteria are necessary for the successful growth of alfalfa. New lands are the only place where inoculation has been found at all beneficial in Wyoming soils. Where barnyard manure is used or crop residues plowed under to increase the humus supply there has been no trouble in getting a successful stand of alfalfa without inoculation.

Time to Seed.

The establishment of a stand is the important thing. If a good stand is obtained and there is the proper development the first year there need be no further fear except for winterkilling, and the future success of the field is certain.

The time of seeding is not so important if soil and moisture conditions are favorable, and there is time enough for the plants to establish themselves before the close of the growing season. Sowings made in the spring, early summer, late summer, and even in the fall have been successful under Wyoming conditions, but taking all factors into consideration, spring sowing has proved the best. At the Experiment Station the most successful seeding has been done in May. The most important consideration, however, is the previous preparation of the soil. Too much attention cannot be given to this point. Given clean,

fertile land, deeply plowed, and well tilled, so that the seed bed conditions are ideal, there need be no fear but that a successful stand of alfalfa will be obtained.

The Amount of Seed to Sow.

No set rule as to amount of seed to sow per acre can be given. From 10 to 20 pounds are used in various parts of the state. The error is generally on the side of too heavy rather than too light seeding. The practice at the Station has been to sow 10 pounds per acre. This has given good stands in every instance and is considered sufficient for irrigated conditions. Good, tested seed should be used, however, so that one may know just the amount he is sowing. Ten pounds of 50 per cent seed will not be sufficient. On non-irrigated lands 4 to 5 pounds of seed per acre will be sufficient for drilling, or 1 to 3 pounds if planted in rows to cultivate.

The Nurse Crop.

In the non-irrigated sections the growing of alfalfa with nurse crop is not advised. There is usually no more moisture than is needed by the alfalfa. Under irrigation a nurse crop of oats or barley may be used to good advantage if moisture and soil conditions are favorable. Fifty pounds of oats or barley is sufficient. If the nurse crop gets too thick and appears to shade the alfalfa too much, it can be cut for hay. If conditions are all favorable, the nurse crop can be allowed to mature grain. In either case some crop is obtained the first year, while if the alfalfa is seeded alone no crop is obtained until the second year. The nurse crop also helps to keep down the weeds if the soil is foul. This is especially true when sowed rather early in the spring. Alfalfa can safely be seeded earlier than is the general practice over the state. The young alfalfa plants grow well in cool weather and will stand considerable cold when well started. The better developed the alfalfa becomes before the hot, dry weather of summer, the more chance it has of withstanding the winter successfully.

Methods of Seeding.

Alfalfa may be planted with the drill or it may be broadcasted. Both methods have been equally successful at the Experiment Station. The ordinary grain drill with the grass seed attachment is all right if care is taken that the seed is not planted too deep. The drill disks often go in the ground deeper than they appear to and the alfalfa seed following them down is liable to be covered too deeply. Alfalfa should have a covering of not more than half an inch in fairly heavy soil, and not more than one inch in light soils.

There is less danger of getting the seed too deep when it is broadcasted. The broadcasting may be done with the hand seeder or a combined alfalfa cultivator and seeder. After being seeded in this way the field should be harrowed. This will cover the seed to just about the proper depth.

Irrigation.

After seeding, if the soil is in good condition as regards tilth and moisture, the alfalfa field will require no more care until it is time to irrigate. At this time the alfalfa plants should be at least three or four inches high. It is better to postpone the first irrigation as long as possible and then irrigate heavily. This will be better than several light irrigations.

The later irrigation does not check the growth of the crop as the earlier irrigation often does since the weather is warmer and the water is warmer. The irrigation water is cold early in the season and when applied to the crop often checks the growth for several days. The desirability of delaying irrigation also holds after the crop has become established. At the Station it has been found that the first irrigation given after the crop was several inches high caused a much more rapid growth than when the water was applied before the growth started in the spring.

At the Station one irrigation for each crop has usually been found sufficient. Only once in six years has it been found necessary to irrigate more frequently. On this occasion a second irrigation was given shortly before the first cutting.

The irrigation for the second crop is given as soon as the first crop is off the ground. On lighter soils in various parts of the state a greater number of irrigations will be found necessary. No definite rule as to the number of irrigations can be given. The need of irrigation must be determined by the condition of the soil and the crop. A good rule is to wait until the crop is in real need, then irrigate thoroughly. The flooding method is generally used in the irrigation of alfalfa. As large a head of water as can be handled should be used and should be run over the field as rapidly as possible. The water should not be allowed to stand on the surface of the ground. Water allowed to stand on the surface will cause the alfalfa plants to turn yellow. The kind of soil, however, determines to a large extent the methods of irrigation. In general, lighter and more frequent irrigations are necessary on sandy soils, while heavier and less frequent irrigations can be applied to clay soils. In other words slow irrigations for clay and rapid irrigations for sand are economical.

Fall irrigation of alfalfa is also beneficial if not done too late. A fall irrigation will usually postpone the spring irrigation. Too late irrigation in the fall by allowing the ground to freeze up while still soggy often causes winterkilling.

Cultivation or Renovation.

The alfalfa crop needs cultivation. The first spring after seeding the plants will not be firmly enough established to stand a severe cultivation. A harrowing with the spiketooth will be sufficient at this time. After this, however, the cultivation should be thoroughly done each year. An alfalfa cultivator of some kind should be used. If the disk harrow is used, it should be run with the disks straight. The alfalfa plants should not be severely cut up.

The use of the old-fashioned porcupine type of renovator is no longer advised. In fact, the implement is no longer manufactured. It was found to be injurious to the alfalfa plants, because its sharp spike-shaped teeth often strike down in the

center of an alfalfa crown without splitting it, but leaving a hole to fill up with water, thus forming an excellent place for the development of fungi and bacteria. The result is that the plant soon dies.

The newer types of alfalfa cultivators, however, are very beneficial to the crop. The spring-tooth alfalfa harrow is a good implement, as is also the alfalfa cultivator with the seeding attachment. In this implement the teeth have play enough to jump over or around the crowns without cutting them, cleaning out the weeds and loosening up the soil very thoroughly. By means of the seeding attachment, bare places in the field can be reseeded at the time the cultivating is being done. The cultivaing should be done early in the spring before growth starts and again after the first cutting.

Cutting and Curing the Crop.

Cut when the crop is about one-third in bloom, is a generally accepted rule for cutting alfalfa. This does not always apply to the best advantage, however, as the time of bloom varies in different years. A better rule to follow is to cut when the new shoots start at the base of the stems. Some years these will be developed too far by the time the crop is one-third in bloom, and cutting at this time injures the second crop quite severely.

At the Station the plan is to rake up the hay close behind the mower. It should not lie in the swath more than half a day after being cut. With a side delivery rake the hay can be put into the windrow very green, where it can be put up into shocks and allowed to cure. In this way all of the leaves are saved and the hay has a brighter color when cured. Since about 65 per cent of the nutriment of the plant is found in the leaves, it is very important that the leaves be saved. If the hay is allowed to cure in the swath before being raked up many of the leaves are lost. It takes from four to six days of good weather for the hay to cure in the shock. A little salt added to each load of hay when it is put in the stack

or the barn will improve the quality and prevent heating to some extent.

Stack Burning.

Many inquiries have come to the Station in regard to stack-burning alfalfa hay. Many of the stockmen of the state want their hay stack-burned for feeding purposes, holding that it has a higher feeding value and that the stock eat it better. The following article by Mr. A. L. Campbell, formerly County Agent of Fremont County, Wyoming, is of interest. He says:

> Tests comparing the feeding value of bright alfalfa hay and "stack-burned" indicate the stack-burned has the greater feeding and fattening value per ton. The Kansas Experiment Station has made tests of hay sent from the Lander Valley which prove that stack-burned alfalfa has a higher per cent of digestible nutrients than does other hay taken from the same field. At least three or four feeders in this county (Fremont) have made comparative tests, alternating from one kind to the other and have satisfied themselves that the stack-burned is eaten more readily and fattens more rapidly than does the bright, clear or "pea green" hay for either cattle or sheep.
>
> In order to have stack-burned hay, it is necessary to put the alfalfa into the stack as soon as possible after cutting. A process of fermentation then takes place similar to that which takes place in a silo. The fermentation breaks down the woody or crude fiber in the stems of the plant and makes more of it digestible. All of the leaves are also saved when alfalfa is put up by this method.
>
> There is no doubt that the feeding value of the alfalfa is increased by this method, but it costs more, as the hay is heavier to handle and is usually too dusty to feed to horses. If the hay is to be fed on the farm the stack-burning will probably pay, but if the hay is to be sold the hay should be allowed to cure in such a way that it will have the bright "pea green color".

Growing Alfalfa Seed.

In many sections of Wyoming conditions are ideal for the production of alfalfa seed. Wyoming seed finds a ready market at home and in surrounding states. Good seed is produced under dry-farm conditions and under irrigation. One important factor in successful alfalfa seed production is that the moisture supply be limited at the time the alfalfa is in bloom and the seed being formed.

The second crop is usually left for seed under irrigated conditions, but the water is kept away from this crop so that the seed may form. At the higher altitudes of the state it is necessary to leave the first crop for seed on account of the shortness of the season; and unless the season is very dry no irrigation will be needed.

One can usually foretell a good seed crop by the appearance of the plants. Vigorous branching, a growth not too rank, and a uniform blossoming period indicate good seed production.

The seed should be harvested while the pods are still somewhat green. If the pods are allowed to attain more than a yellowish color there will be much shattering. The crop may be cut with the mower and allowed to cure on the ground. A self-binder can be used to good advantage and the bundles set up in shocks. This facilitates handling at threshing time. The threshing may be done with the ordinary grain separator, but this is not as satisfactory as the clover huller. Yields of from 300 to 600 pounds per acre should be obtained under Wyoming conditions.

Winterkilling.

Occasionally reports of winterkilling of alfalfa come to the Station and many theories of the causes and prevention of the same are advanced. There are several causes of winterkilling. Among these are insufficient growth the first year, pasturing too closely late in the fall, watering too late in the fall, becoming too dry, and lack of winter protection. New seeding should be done early enough so that the plants will get a good start before freezing up. If the alfalfa has been sowed alone and the field is weedy, it should be mowed early in the fall and the material allowed to remain on the ground as a mulch. If the alfalfa was seeded with a nurse crop the stubble will afford winter protection.

Alfalfa should not be pastured too closely after the last cutting. The tramping of animals when the ground is soft

is injurious. Pasturing after the ground is frozen, however, will do no harm.

Late irrigation sometimes causes winterkilling by saturating the soil so late that it freezes up in this condition. Fall irrigation is beneficial, provided it is done early enough so that the water has time to go down before the ground freezes. It is safer to give the last irrigation as soon as possible after the last cutting is out of the way. This will generally give the plants a sufficient moisture supply to carry them through the winter and up to the time of the first spring irrigation. A top-dressing of barnyard manure will give the alfalfa plants some winter protection and will also add fertility to the soil. This top-dressing of manure is especially beneficial to the alfalfa field on the dry farm.

Combating Diseases and Insect Enemies.

Wyoming alfalfa is subject to but few diseases. The root-rot has appeared in old fields in some parts of the state. This disease usually does not make its appearance until the plants are five or six years old. Crop rotation will keep the alfalfa free from this disease. Breaking up the alfalfa land and growing a crop or two of grain and a cultivated crop, and then seeding back to alfalfa, keeps the disease completely in check.

Stem blight is a disease which occasionally is brought on by the plants being affected by early spring frosts. The freezing affects the tender stems, causing them to soften, and they are attacked by bacteria, causing blight, and growth stops. When alfalfa fields become seriously affected by the blight the crop should be cut at once, so that the second crop can come on without hindrance.

Insect pests are not numerous. Grasshoppers occasionally do some harm. Cultivating the field early in the spring is beneficial, since it exposes the young grasshoppers to the spring frosts and the attacks of birds. The use of the "hopper dozer", an implement which when drawn across the fields knocks the insects into a pan of oil, is sometimes necessary when the pests become serious.

Wyoming has thus far been practically free from the alfalfa leaf weevil. Some reports of damage done by the weevil have been received, but upon investigation they have proved false alarms. On several occasions when such reports came to the Experiment Station specimens of the insect were sent in and in every case the pest was identified as the alfalfa looper. The looper occasionally does some damage to alfalfa and other plants. It is not common, however, and appears only occasionally. It was quite numerous in the Big Horn Basin and in the central part of the state in 1914, but was not reported at all in 1915.

During the summer of 1914, the Agronomist received a letter from the Montana Station stating that reports of the alfalfa weevil doing destructive work had come from the Big Horn Basin. This office gave them the information on hand, namely, that the reports had been investigated and the pest found to be the alfalfa looper. To verify this the Montana Station sent a man into the section to investigate. He found no alfalfa weevil, but the alfalfa looper was found in abundance, thus corroborating the investigations of this office.

The looper is a green worm something like but somewhat larger than the so-called "measuring worms" or "span worms", often seen on garden plants. It usually does not do much damage to alfalfa and generally disappears after the first cutting. If the loopers are abundant the alfalfa should be cut as soon as possible and the field given a thorough irrigation. There is then little danger of their injuring the second cutting.

Since the alfalfa looper appears occasionally in sufficient numbers to do considerable damage and to cause some uneasiness on the part of the alfalfa grower, the following rules for the control of the pest given by the Montana Station are given here:

> The loopers become noticeably abundant shortly before time to cut the first crop. They are not easily seen until one looks closely, and careful examination of the fields which the owner has seen daily may reveal a surprising number of the worms.

As the season advances the larvae become larger by the time the first crop is cut. They will not eat the hay and when the green alfalfa is removed, they are forced to search for food. They go to adjoining fields in great numbers and an effort should be made to prevent injury to the other crops, such as sugar beets and corn. To accomplish this a trial of the following methods is suggested:

1. Where practicable, run a ditch of water around the alfalfa field or between it and the other field to be protected, to prevent the crawling worms from crossing.

2. Spray heavily with Paris Green or Arsenate of Lead around the edges of the field, wherever the worms may be found feeding. In some instances it may be well to leave a strip of alfalfa around the edge of the field, and in large fields some in the middle, as bait, which should be poisoned. This should be later cut down and, when dry, burned, to prevent poisoning domestic animals. Paris Green may be used at the rate of three to four pounds to the hundred gallons of water. The addition of soap at the rate of four pounds to one hundred gallons of water aids in making the poison spread and stick.

Alfalfa in the Crop Rotation.

Experience has shown that alfalfa fields produce better crops when plowed up every four or five years and reseeded. In other words, a crop rotation system increases the yields of alfalfa and also the yields of other crops. A. L. Campbell, formerly County Agent in Fremont County, reports yields of alfalfa and grain crops more than doubled in that county by a crop rotation system in which alfalfa fields were plowed up every four years and grain crops and potatoes grown for two or three years, the land then being seeded back to alfalfa.

The usual plan of rotation is to allow the alfalfa to stand four years. It is then broken up and planted to a cultivated crop or grain crops for two or more years and then seeded back to alfalfa. It is usually better to grow grain the first year after the alfalfa breaking. If a root or other cultivated crop is grown the first year the many alfalfa plants that have not been killed will hinder the cultivation, but where grain is grown the alfalfa plants will not hinder its growth and a second plowing will kill out the remaining plants.

In the sugar-beet sections alfalfa works well in the crop rotation. Alfalfa land is excellent for beets. If plowed thoroughly, the beets can be grown the first year, but a grain crop

will follow the alfalfa better the first year after breaking. Plant beets the second year and the following year the land may be seeded back to alfalfa with grain as a nurse crop. In this rotation the alfalfa stands four years, being followed by two crops of grain and one cultivated crop. This permits the barnyard manure to be used on the alfalfa where it will be of the greatest value to that and the other crops.

Breaking Up Alfalfa Land.

There is often a good deal of trouble in getting rid of alfalfa unless the breaking is properly done. The alfalfa or breaker bottom should be used on the plow and the share kept very sharp so that it will cut through the crowns and not slide around them. The best time to break is in the fall after the last cutting. The breaking should be only deep enough to cut the crowns. A second plowing should be made in the spring; this should be deeper. The crown having been cut off, this plowing will be easier and will kill out practically all of the plants, so that a cultivated crop may be grown the first year, if so desired. Grain may be grown with one plowing if the saving of time is important. The second plowing, however, will be found to pay.

Pasturing Alfalfa.

While alfalfa is primarily a hay plant, it also affords excellent pasture for all farm animals. It is especially good for young, growing animals. When pastured by cattle and sheep, however, caution in regard to bloat must be observed.

Alfalfa should not be pastured too closely by any kind of stock, unless it is desired to destroy the stand. If the field is to be broken up in the crop rotation the animals may be allowed to eat the plants down to the ground. Animals should not be permitted to run on alfalfa when the ground is wet. The tramping of large animals injures the crowns of the plants. The heavy pasturing of alfalfa is hazardous under any conditions. Therefore, other pasture should be provided, so that intensive pasturing of the alfalfa fields will not be

necessary. Alfalfa seed may be used to good advantage in pasture mixtures.

Alfalfa and Timothy.

In some parts of the state it is a common practice to sow timothy with the alfalfa; the alfalfa-and-timothy hay being quite popular with many stockmen.

A mixture of five pounds of timothy and five pounds of alfalfa per acre was sowed at the Experiment Station some years ago. The timothy did not seem to do well under local conditions and was soon replaced by the alfalfa. In many parts of the state, however, conditions seem to be favorable for the growing of these two plants together. The alfalfa comes into bloom a little ahead of the timothy, so the alfalfa will be more mature when cut than when grown alone. This is not detrimental to the feeding value of the hay, but, on the other hand, makes it more valuable for feeding horses. The second crop comes on without the timothy and consists of clear alfalfa.

On lands that are suitably drained and where the water table is not too near the surface, the alfalfa and timothy mixture will probably be found valuable for permanent meadows.

Alfalfa on the Dry Farm.

But little experimental work along the line of growing alfalfa without irrigation has been done at the Experiment Station owing to the fact that the dry-farm work of the state is being conducted by the State Farm Board and it has been deemed wise to avoid duplication of work as far as possible.

Numerous inquiries regarding the growing of alfalfa on the non-irrigated farm have been received at the Station, so it seems well to include a brief discussion of the subject in this bulletin.

Improvements in methods of dry-land farming and improvement in varieties by selection and otherwise, have made it possible to grow alfalfa in sections heretofore considered too dry for its utilization.

Much alfalfa is still broadcasted on the dry land, but the cultivated-row method is becoming more and more popular. The crop, whether grown for hay or seed, is improved by the row method. By this method there is more certainty of retaining it if moisture is scarce.

For growing alfalfa on the dry farm the hardy varieties of seed, such as the Grimm, Baltic or "Dry Grown", should be selected.

The land should be as carefully prepared for seeding as under irrigation, whether the seed is to be sowed broadcast or in rows. A deep-plowed, well-packed seed bed is necessary in either case. A thin uniform stand in rows 36 to 42 inches apart will give better results than seeding closer together. Only about two pounds of seed per acre will be required by this method of seeding.

The seeding can be done with an ordinary garden drill or with a grain or grass drill stopping up enough of the spouts so that the rows will be the required distance apart. A corn or beet cultivator can be used for cultivating as soon as the plants are large enough for the rows to be seen.

For the production of seed the row method is not only more certain of producing a crop, but will produce a larger yield, since it affords a better moisture condition and more light to the individual plant.

If it is desired to sow the seed broadcast or to drill in close rows, care should be taken to scatter the seed thin. Four or five pounds to the acre will be sufficient. Thin seeding is more certain to give a good stand than thick seeding. Rather early sowing is also advised. Probably from the first to the middle of May will suit most dry-farm conditions in Wyoming.

ACKNOWLEDGMENTS.

Much credit for this bulletin is due Mr. Ross L. Bancroft, who was Student Foreman at the Agronomy Farm for three years. He had direct charge of the farm during this time.

Mr. P. F. Meyers, Assistant in Agronomy, also gave valuable assistance in the compilation of tables and in the preparation of diagrams and pictures.

Material for Further Reading.

Those who desire more information in general in regard to alfalfa are referred to the following books and bulletins on the subject:

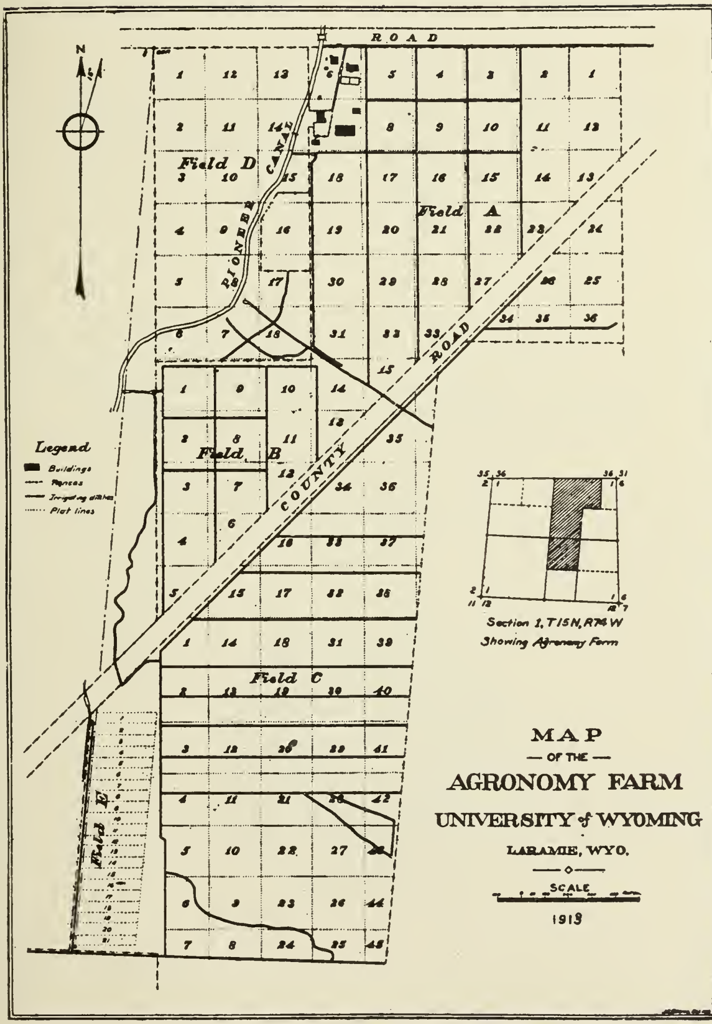
Books:

Alfalfa in America, by Joseph Wing.
Forage Plants, by Chas. V. Piper.

Bulletins by the U. S. Department of Agriculture, Washington, D. C.:

Farmers' Bulletin No. 339, Alfalfa.
Farmers' Bulletin No. 373, Irrigation of Alfalfa.
Farmers' Bulletin No. 495, Alfalfa Seed Production.
Bureau of Plant Industry Bulletin No. 209, Grimm Alfalfa in the Northwest.

Booklets of the International Harvester Co., Chicago, Ill.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N
Field D
PIONEER CANAL
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COUNTY ROAD
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Field C
Field E
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Buildings
Fences
Plot lines
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MAP
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UNIVERSITY of WYOMING
LARAMIE, WYO.
SCALE
1913

BULLETIN NO. 112 JANUARY, 1917

UNIVERSITY OF WYOMING

AGRICULTURAL EXPERIMENT STATION

LARAMIE, WYOMING

The Poisonous Properties of the Two-Grooved Milk Vetch

(Astragalus bisulcatus)

By O. A. Beath and E. H. Lehnert

Bulletins will be sent free upon request
Address: Director Experiment Station, Laramie, Wyoming

SUMMARY.

I. Milk vetch has been proved to be poisonous to cattle. Suspicion is held regarding its effect upon sheep.

II. Eighty to ninety per cent of the animals affected die.

III. Water easily removes the active poison from green or air-dried material.

IV. All parts of the plant contain poison with a slight excess in the leaves.

V. The poison is neither precipitated by basic acetate of lead nor decomposed at the boiling point of water.

VI. It can be deprived of its toxicity by boiling with dilute acids (indicating its probable glucosidic character).

VII. The poison is non-alkaloidal.

VIII. A definite crystalline substance has been isolated, giving chemical reactions common to glucosides.

IX. Thus far no chemical antidote has been obtained.

X. As indicated by the physiological action of the poison, drugs that stimulate the heart and nervous system should prove beneficial in the case of vetch-poisoning.

The Poisonous Properties of the Two-Grooved Milk Vetch

(Astragalus bisulcatus)

PART I. CHEMICAL.

BY O. A. BEATH.

INTRODUCTION.

A brief account of the two-grooved milk vetch (*Astragalus bisulcatus*) is put in the form of a preliminary bulletin at this time, largely to warn stockmen of its poisonous nature. Authorities on poisonous plants make no mention of this particular vetch as being suspected of producing toxic effects. As a consequence it is safe to conclude that certain conditions undoubtedly prevail which cause it to be extremely variable in its toxicity. Moisture unquestionably influences the activity of the toxic principle, inasmuch as it is readily soluble in water. Certain stockmen have used this vetch for forage purposes without any apparent ill effects, thereby illustrating the small degree of danger when the plant is well dried.

The attention of the research laboratory was called to the plant's probable poisonous character rather late in the season and as a result the data available at this time have to do only with well matured material. Therefore, the seasonal factor is yet to be determined.

It is a matter of regret that direct feeding experiments could not have been employed to verify the results obtained by using water and alcoholic extracts. However, the project is to be continued on a larger scale this coming summer.

GENERAL CHARACTER OF THE PLANT.

Milk vetch is found growing on plains and in valleys throughout the Rocky Mountain region. It appears during the month of May and goes to seed the latter part of July. The following description of the plant is given in Bulletin No. 76 of the Wyoming Experiment Station:

This is one of the large, coarse vetches, usually growing in dense clumps and becoming 2 to 3 feet high. It produces purple blossoms in profusion and these are followed by an abundance of pods from one-half to nearly an inch long and having two rather deep furrows on the upper side. The plant is rather rank scented, especially when young, and, unless other forage is scarce, is not browsed down until the pods begin to mature.

The Two-Grooved Milk Vetch.

All parts of the plant contain poison apparently quite evenly distributed throughout.

Data gathered from stockmen would indicate that this species of vetch is poisonous to cattle and sheep. Nothing is known in regard to its effect on horses. The laboratory has obtained no direct evidence that sheep have been killed by eating it, although a number of suspicious cases are on record.

During July, 1916, E. B. Foster of Casper reported a loss of nine calves and ten cows out of a herd of forty-one head. He states, "No two acted in the same way. However, all evidenced signs of craziness. On some the effect would hardly be noticed until one went near them, and then they would suddenly act frightened and in attempting to get away would stumble and fall or have a fit." All animals which showed signs of milk-vetch poisoning died.

Experimental.

The plant material submitted for investigation was secured from Mr. Foster of Casper, Wyo. Green plants could have been obtained in the vicinity of Laramie, but it seemed advisable to deal with those authentically known to have given trouble.

After drying, the seeds, pods, leaves, and stems, respectively, were coarsely ground and placed in air-tight containers.

Test for Hydrocyanic Acid.

Five hundred grams of air-dried material were placed in a flask and saturated with water. Steam was then passed into the flask for a period of three hours. The distillate gave negative results for hydrocyanic acid. Tests were made upon each part of the plant. The residue remaining in each case was acidified with strong sulphuric acid and again treated as above. Negative results were obtained for combined hydrocyanic acid.

The distillates had an odor particularly disagreeable. The distillate from the seeds yielded a small amount of volatile oil which proved to be non-toxic in character.

Test for Active Enzymes.

One hundred grams of finely ground leaves and stems were digested with three liters of water at a temperature of 37.5° C. for a period of 48 hours. The aqueous portion was separated and mixed with an excess of alcohol. A profuse precipitate was formed which soon settled to the bottom of the flask. The alcohol was removed and the solids remaining were washed with a little cold alcohol and subsequently dried. A portion added to a dilute solution of amygdalin failed to produce hydrolyses to any appreciable extent. This indicates the absence of *Beta*-glucose or allied enzymes capable of hydrolyzing *Beta*-methyl glucosides. Not having any representative of the *Alpha*-methyl glucosides the presence of *Alpha*-glucose could not be ascertained.

Water Extracts.

In carrying out the work of determining the character of milk vetch it was quickly demonstrated that water was a better solvent for the removal of the poisonous principle than alcohol, ether, chloroform, or acidulated water.

The concentrated water extracts were invariably dark, resembling plant resins obtained by alcoholic percolation. Residues obtained by alcoholic treatment were dark and in general did not differ in appearance from those derived by maceration with water. If to a concentrated alcoholic extract a large volume of water was added, a bulky grayish precipitate was thrown down. This, upon closer examination, proved to be calcium sulphate.

With the exception of three extracts, all were given internally to full-grown rabbits. The three administered otherwise were given to an old ewe, a yearling calf, and a female dog.

The extracts used in the tests were prepared as follows:

No. 1.

Seeds and pods (dry)	3 oz.
Alcohol (95%)	10 oz.

Mixture digested 24 hours at a temperature of 37.5° C., concentrated to small bulk and diluted with 2 oz. of water.

No. 2.

Leaves (dry) .... 3 oz.
Alcohol (95%) .... 10 oz.

Treated the same as No. 1.

No. 3.

Seeds and pods (dry) .... 3 oz.
Water .... 15 oz.

Digested for 24 hours at 37.5° C. Aqueous portion separated and concentrated to 2 oz.

No. 4.

Leaves and stems (dry) .... 46 oz.
Water .... 350 oz.

Same treatment as No. 3, concentrated to 75 oz.

No. 5.

Stems (dry) .... 6 oz.
Water .... 12 oz.

Treated as in No. 3, concentrated to 5 oz.

No. 6.

Leaves and stems (dry) .... 87 oz.
Water .... 150 oz.

Same treatment as in No. 3, concentrated to 25 oz.

No. 7.

Whole plant (dry) .... 22 oz.
Water .... 150 oz.

Digested 48 hours at 37.5° C. Aqueous portion separated and concentrated to 25 oz. Treated with slight excess of basic lead acetate. Lead precipitate removed, washed, and suspended in large volume of water. Lead precipitated as lead sulphide. Remaining solution concentrated to 5 oz. Labeled Solution "A".

That portion of the original water extract not precipitated by basic lead acetate was treated with hydrogen sulphide to remove lead and concentrated to a volume of 5 oz. Labeled Solution "B".

No. 8.

Leaves, stems, and pods (dry)	3 oz.
Water	10 oz.

Digested 48 hours at the boiling point of water. Filtered. Concentrated to 2 oz.

No. 9.

Leaves, stems, and pods (dry)	3 oz.
Water	10 oz.
Sulphuric acid (5%)	1 oz.

Digested 48 hours at 90° C. Filtered. Sulphuric acid removed. Solution concentrated to 2 oz.

Results as to Activity of Extracts.

Extract No. 1. Volume, 2 oz.

Given internally to full-grown rabbit at 11 a. m. No symptoms at 5 p. m. Died during the night.

Extract No. 2. Volume, 2 oz.

Given to full-grown rabbit at 11 a. m. No symptoms at 5 p. m. Died during the night.

Extract No. 3. Volume, 2 oz.

Given internally to full-grown rabbit at 11 a. m. Decided symptoms at 1:30 p. m. Restoratives administered. Died at 6 p. m.

Extract No. 4. Volume, 75 oz.

Given by drench to an old ewe October 4, at 2:45 p. m. No symptoms indicated.

Extract No. 5. Volume, 5 oz.

Given by drench to dog at 10 a. m. Decided symptoms of nausea at 10:30 a. m. The dog vomited repeatedly with marked straining. In a few hours the symptoms disappeared.

Extract No. 6. Volume, 25 oz.

Given to yearling calf October 31, at 11 a. m. No symptoms observed until the following day, at 9:45. Animal was unable to rise, and had a temperature of 94.5° F., pulse 74, respiration 12. Died at 2 p. m., November 1.

Extract No. 7. Volume, 5 oz.

Solution "A" given to full-grown rabbit at 1 p. m. Died at 6 p. m. Solution "B" given to rabbit at 1:30 p. m. No indications of poisoning.

Extract No. 8. Volume, 2 oz.

Given internally to full-grown rabbit at 11 a. m. At 1 p. m. the usual symptoms were observed, such as non-co-ordinated movements and loss of control. Rabbit died at 4 p. m.

Extract No. 9. Volume, 2 oz.

Given internally to full-grown rabbit at 11 a. m. No symptoms indicated.

Conclusions.

1. The data so far obtained indicate that a definite active poison is present.

2. In no case did a rabbit live when given freshly prepared extracts.

3. Although the old ewe showed no effects from a dose of extractive material equivalent to fifteen pounds of the green plant, yet it is not safe to presume from this experiment that the vetch is not poisonous to sheep, for (1) only one sheep was tested and (2) green plants may produce an effect different from that of the extract of the dried ones.

4. On account of the ease with which a dog can empty its stomach by vomiting when irritants are given, we have concluded that in our experiment with the dog not enough of the poison was absorbed to manifest itself.

Future Work.

Having studied the general nature of the active poison, our next step will be to conduct feeding experiments, typifying range conditions as far as possible, and to study the problem of milk vetch poisoning from the point of view of symptoms and specific antidotes.

PART II. PHYSIOLOGICAL.

BY E. H. LEHNERT.

How the Poison Acts.

From experiments carried on with extracts and other preparations from this plant, our observations both before and after death have led to a few definite conclusions. When sufficient poison to cause death is introduced into the system, whether through the stomach or intravenously, it acts quickly, that is it is quickly absorbed, and very soon produces symptoms of paralysis, by its action on the nervous system; the action of the heart is also interfered with, and the poison no doubt kills by acting on this organ. When the poison is administered by the stomach, postmortem examination shows that digestion is stopped immediately, as invariably this organ remains full of food, indicating that the poison is quickly absorbed from the stomach and that the stomach is paralyzed.

Remedies and Methods of Treatment.

Attempts at determining an antidote for the poison were made, and, although few in number, certain conclusions have been reached. Thus far no chemical antidote has been obtained, but from the obvious action of the poison on the heart and nervous system as a depressant, antidotes of a physiological nature would be those that stimulate these organs, such as alcohol, ammonia, strychnine, nitro-glycerine, and digitalis, belladonna or atropine. In our experiments we were able to counteract the poison for a considerable time, although in no case were we able entirely to neutralize its action. It appears, however, very probable that the remedies mentioned should prove very valuable where the amount of poison taken into the system is not too great.

In the administration of remedies in case of poisoning, the following doses and methods would apply: Immediately give to full-grown animal (cow), as a drench, 1 to 2 lbs. of

Epsom salts, dissolved in water; vary dose with size, as in all cases the doses given are for mature animals.

Alcohol should be administered in the form of whiskey, brandy, or gin, in 2 to 4-oz. doses, diluted with an equal quantity of water, the dose repeated every hour.

Aromatic Spirits of Ammonia is one of the best quick-acting heart stimulants, and should be given once an hour in two-ounce doses, diluted with three volumes of water.

Belladonna fluid extract may be used as a heart and nerve stimulant in hourly doses of 2 drachms in a little water. This drug would work well combined with either whiskey or aromatic ammonia.

Digitalis. The tincture digitalis may be given, diluted with water, in 2 to 3 drachm doses every 3 to 4 hours.

For quick action, drugs should be administered hypodermatically, that is, injected under the skin. For this purpose the drugs are very concentrated and put up in tablet form, very soluble in water, and should be administered with the hypodermatic syringe, of which there are many varieties on the market at prices from $2.00 up. For hypodermatic uses in poisoning by vetch, I would suggest a compound tablet consisting of strychnine, nitro-glycerine, and digitalin or atropine, the quantity of strychnine being not over 2 grains; the quantities of other ingredients will not matter materially, as the compounders put them up in the right proportion to give best results. In using the hypodermatic remedy alone, it should be administered once an hour, using clean boiled water to dissolve the tablet, and disinfecting the skin at the point of puncture with any common disinfectant or tincture of iodine. In the majority of cases the worst stages should be over in 3 to 4 hours, and if the vital organs can be kept active during this period, recovery is possible.

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UNIVERSITY OF WYOMING

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LARAMIE, WYOMING

THE EFFECT OF ALKALI UPON PORTLAND CEMENT

By KARL STEIK

Bulletins will be sent free upon request.
Address: Director Experiment Station, Laramie, Wyoming.

UNIVERSITY OF WYOMING
Agricultural Experiment Station
LARAMIE

The Effect of Alkali on Portland Cement.

BY KARL STEIK.

INTRODUCTION.

The word "alkali" as used in the western United States designates the chlorides, sulphates, and carbonates of sodium and magnesium and sometimes of calcium. Sodium carbonate is usually called "black alkali", because the organic matter which it dissolves from the soils makes solutions which have a dark color.

The composition of alkali varies greatly according to the region where it is found. In most cases the sulphates of sodium, magnesium, and calcium are the most abundant salts. The nitrates are present only in very small quantities in this state and, therefore, they are not considered in this work. Alkali from different localities in Wyoming shows great variations in regard to the proportion that is insoluble in 1:1 hydrochloric acid—a variation from 1.6 per cent to 27.9 per cent. The following table shows the variations of ingredients in alkali crusts:

> Acid insoluble part: 1.6 per cent to 27.9 per cent; silica: trace to 0.8 per cent; alumina and iron oxide: 0.1 per cent to 1.6 per cent; calcium oxide: 1.1 per cent to 6.0 per cent; magnesia: 0.2 per cent to 21.6 per cent; sodium oxide: 18.4 per cent to 41.2 per cent; potassium oxide: 0.4 per cent to 1.5 per cent; anhydride of sulphuric acid: 27.6 per cent to 51.4 per cent; carbon dioxide: 0.6 per cent to 3.8 per cent; organic matter: trace to 4.2 per cent; chlorine: 0.1 per cent to 1.8 per cent.

The concentration of the alkali salts dissolved in water is also subject to great variations. The water in small alkali lakes may even become saturated with these salts, usually

either sodium sulphate or magnesium sulphate, or with both of them with smaller quantities of sodium chloride present.

I. Chemical Changes.

In order to study the chemical changes and the resulting physical changes, which take place in cement when in contact with alkalis, cement cubes and briquettes were put in solutions of various salts of different concentrations; the proportion of water or solution to cement being the same in all cases, namely, 1 cc. per gram of block, whether of neat cement or mortar. Unless otherwise stated, the blocks were allowed to set 7 days in water before being immersed in the solutions. The strength of these solutions varied from 1 per cent to 10 per cent, and were made up as follows:

No. 1. 5 per cent $NaCl$.
No. 2. 5 per cent $MgSO_4$.
No. 3. 1 per cent Na_2SO_4.
No. 4. 5 per cent Na_2SO_4.
No. 5. 10 per cent Na_2SO_4.
No. 6. 5 per cent Na_2CO_3.
No. 7. 5 per cent $NaHCO_3$.
No. 8. 1 per cent $NaCl$.
No. 9. 1 per cent $NaCl$, 1 per cent Na_2CO_3, and 3 per cent Na_2SO_4.
No. 10. 1.25 per cent $NaCl$, 1.25 per cent Na_2SO_4, 1.25 per cent $MgCl_2$, and 1.25 per cent $MgSO_4$.
No. 11. 1.33 per cent $CaCl_2$, 1.33 per cent $MgCl_2$, and 1.33 per cent $NaCl$.
No. 12. 1.66 per cent $NaCl$, 1.66 per cent Na_2CO_3, and 1.66 per cent Na_2SO_4.
No. 13. 3 per cent $NaCl$, 3 per cent Na_2CO_3, and 3 per cent Na_2SO_4.
No. 14. 2.5 per cent $NaCl$ and 2.5 per cent Na_2SO_4.

Table I shows the analyses of cements that had been in solution for 30 months.

TABLE I—*Showing the Chemical Analyses of Blocks of Neat Cement that Have Been Immersed for 30 Months in Various Solutions.*

Lab. No.	SOLUTION	Water of constitution	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	Na_2O and K_2O	SO_3	Cl	CO_2	Total	Oxygen for chlorine
		%	%	%	%	%	%	%	%	%	%	%	%
15	(1) Distilled water	21.2	18.66	44.13	8.33	2.67	3.96	1.44	1.21	*Trace	0.94	101.64	....
	(2) In solutions of single salts:												
	(a) 7 days in water before immersion.												
1	NaCl, 5 per cent	15.32	18.55	46.29	8.45	1.20	3.01	1.83	0.55	5.74	0.42	101.36	1.36
2	$MgSO_4$, 5 per cent	17.60	17.91	42.36	4.61	1.33	4.01	1.37	10.20	0.08	1.16	100.63	....
3	Na_2SO_4, 1 per cent	15.97	18.82	42.70	7.27	1.60	2.10	2.24	8.38	*Trace	0.34	99.42	....
4	Na_2SO_4, 5 per cent	18.80	17.88	40.53	5.82	1.03	1.88	2.60	11.16	0.66	0.41	99.77	....
5	Na_2SO_4, 10 per cent	20.63	15.72	43.25	5.00	0.96	2.55	2.37	10.04	0.11	0.60	101.23	0.11
	(b) 14 days in water before immersion.												
6	Na_2SO_4, 5 per cent	17.5	18.31	40.10	5.03	2.28	1.63	2.66	11.88	0.14	0.68	100.21	0.14
7	NaCl, 5 per cent	17.4	18.58	43.92	4.70	3.07	2.61	2.10	0.78	6.07	1.20	100.43	0.43
8	Na_2CO_3, 5 per cent	17.6	18.53	42.26	8.14	3.58	1.08	3.80	0.34	0.04	5.64	100.68	0.34
9	$NaHCO_3$, 5 per cent	15.0	19.80	50.38	6.17	1.63	0.61	2.44	0.08	*Trace	3.60	99.71	....
12	NaCl, 1 per cent	20.84	17.94	46.43	8.73	3.19	0.39	1.63	0.50	0.98	0.84	101.47	0.98
	(c) 14 days in water and 3 months in air before immersion.												
10	NaCl, 1 per cent	19.39	18.64	50.05	7.70	3.10	0.92	1.20	0.63	1.02	0.26	101.91	1.02
11	Na_2CO_3, 5 per cent	17.70	18.96	41.83	7.52	3.38	0.80	3.57	0.41	0.02	6.63	100.82	0.02
	(3) In solutions of mixed salts; 7 days in water before immersion:												
14	1.25 per cent each of NaCl, Na_2SO_4, $MgCl_2$ and $MgSO_4$	18.13	21.30	30.90	7.63	2.86	3.22	4.16	7.67	5.98	9.59	101.44	1.44
16	Same as No. 14	18.74	19.61	38.60	8.90	3.54	4.67	2.02	3.41	2.30	†	101.71	1.79
17	1.33 per cent each of $CaCl_2$, $MfCl_2$ and NaCl	20.09	19.77	45.16	9.12	3.18	3.17	1.01	0.36	1.83	†	103.69	1.83

*Not determined.
†Very little; not determined.

Crystalline Deposits.

From the solutions of sulphates of sodium and magnesium, hydrated calcium sulphate ($CaSO_4$, $2H_2O$) was deposited upon the surface of the cement, either as single crystals or as groups of crystals, radiating from a center, as shown in Figures 1 and 2, or more rarely in the amorphous form. The latter occurred most often in cements low in lime content.

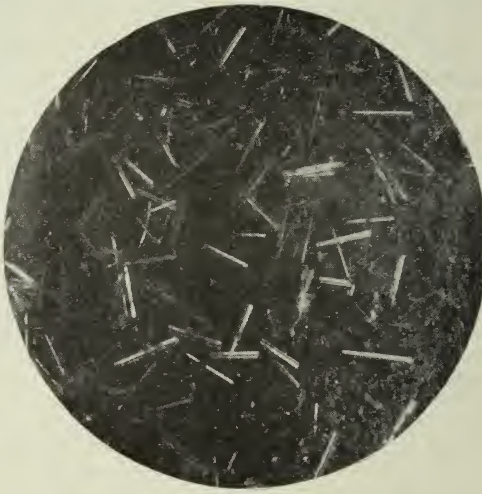

Fig. 1.

The chemical analyses of the calcium sulphate crystals gave the following averages: Water 21.0 per cent; CaO, 32.5 per cent; So_3, 46.3 per cent. The crystals selected for the analyses were entirely free from adhering cement and solution. Since $Ca(OH)_2$ is present in cement, it must be assumed that the following reaction took place with sodium sulphate:

$$Ca(OH)_2 + Na_2SO_4 + aq. = CaSO_4.2H_2O + 2NaOH + aq.$$

In the case of magnesium sulphate, magnesium hydroxide is formed and deposited as a flocculent precipitate. It was obtained in a fairly pure state by the repeated suspension in water of finely ground mixtures containing magnesium hydroxide and cement, and their subsequent settling and separation in a

FIG. 2.

separatory funnel. The magnesium hydroxide was dried between filter paper and weighed for analysis. The analyses gave the following average: Water, 59.6 per cent; magnesium oxide (MgO), 39.1 per cent. Small quantities of SiO_2, CaO, and CO_2 were also present. Accordingly, in $MgSO_4$ solutions, the following reaction took place:

$$Ca(OH)_2+MgSO_4+aq.=CaSO_4.2H_2O+Mg(OH)_2+aq.$$

From solutions of sodium carbonate, calcium carbonate was formed and deposited on the blocks in small amorphous grains. The sample for analysis was washed free from soluble carbonate, dried, weighed, and dissolved in very dilute hydrochloric acid. Only a very small portion was left undissolved. The solution was then evaporated to dryness. The residue gave CaO, 56.3 per cent, as calculated for the original weight of sample, minus the amount insoluble in dilute hydrochloric acid. Figure 3 shows how the calcium carbonate (the lighter area) is deposited on the cement blocks.

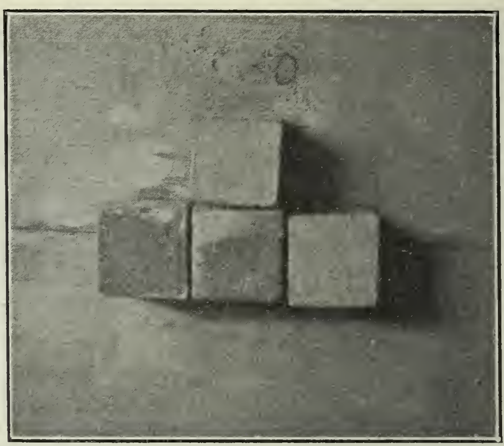

Fig. 3.

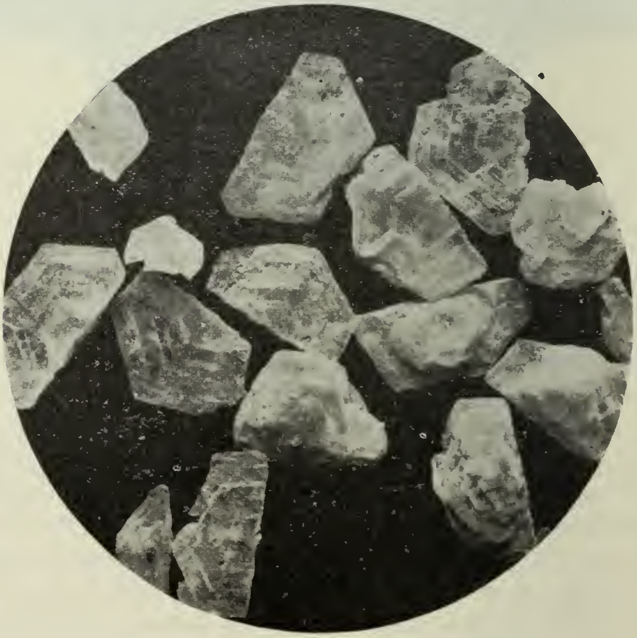

Fig. 4.

From solutions of chlorides of sodium and magnesium, at first only calcium hydroxide was obtained. Figure 4 shows the crystals of calcium hydroxide and Figure 5 shows the crystals as they were formed on cement. The largest crystals were about one-eighth to three-sixteenths of an inch in thickness. The crystals were cleaned from adhering cement and then gave the following analysis: CaO, 75.7 per cent; water, 24.6 per cent; and very little carbon dioxide.

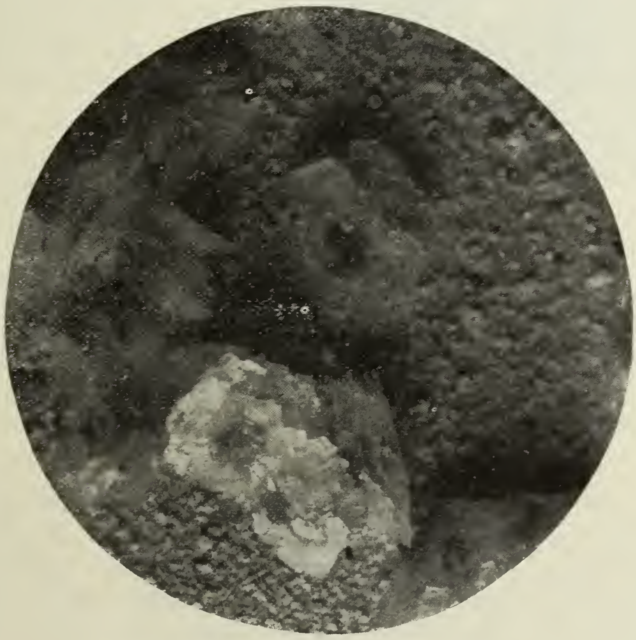

FIG. 5.

The deposits described in the foregoing paragraphs were scraped off the surface of the blocks several times. The time required for the formation of a new visible crop was from two weeks to two months.

Secondary Deposits from Sodium Chloride Solution: Silicates.—On the cement which was in a 5 per cent sodium

chloride solution for approximately three years (solution not changed) crystals appeared which, after cleaning, gave the changed) crystals appeared which, after cleaning, gave the following analytical results: SiO_2, 40.14 per cent; Al_2O_3, 31.48 per cent; Fe_2O_3, 0.11 per cent; CaO, 10.09 per cent; Na_2O, 14.13 per cent; Cl, 4.39 per cent. Figure 6 shows these silicate crystals.

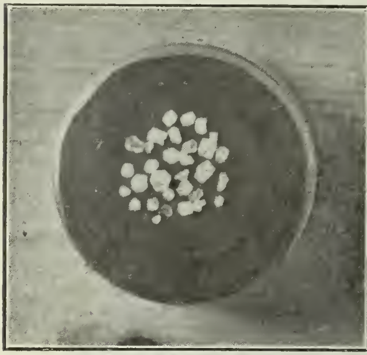

Fig. 6.

Calcium Hydroxide Deposits from Other Solutions.—No deposits of definite composition were obtained in solutions which contained more than one salt, except that calcium hydroxide was obtained from solutions of sodium chloride or magnesium chloride, or from solutions containing both these salts. Calcium hydroxide was also obtained from cement in distilled water and in solutions of sodium hydroxide.

II. Physical Changes.

Strength tests were made before the immersion of the cement in the solutions of alkali salts, then after 12 months, 24 months, 30 months, and 40 months in solutions. After each testing the cement was put into a fresh solution, one cc. of the solution being used per gram of cement or mortar. The blocks were tested for soundness previous to using them for the experiments. The weight of the individual cubes or briquettes never varied more than 3 per cent. A table showing all the individual strength tests for each set of blocks is given in the Appendix. The average compression and tension of each set at the end of each period is given in Table II.

TABLE II—*Showing the Average Strength of Cement Blocks Before and After Being in Salt Solutions for Various Periods.*

Lab. No.	SOLUTION	Before immersion		After being in solution: 12 months		24 months		30 months		40 months	
		Compress	Tension	Compress.	Tension	Compress.	Tension	Compress.	Tension	Compress.	Tension
	I. Neat Ideal in various solutions:	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
	(1) In distilled water for comparison.										
15	Distilled water	7826	494	7145	716	9560	745	10907	677	9877	678
	(2) In solutions of single salts.										
	(a) 7 days in water before immersion.										
1	Sol. 1, NaCl, 5 per cent	6745	284	9675	994	10185	1017	10452	910	7527	747
2	Sol. 2, $MgSO_4$, 5 per cent	7939	664	11615	482	11310	289	10030	651	8073	612
3	Sol. 3, Na_2SO_4, 1 per cent	8827	455	10687	400	10712	806	10282	725	9047	698
4	Sol. 4, Na_2SO_4, 5 per cent	7708	588	8457	644	7045	716	6482	701	6523	632
5	Sol. 5, Na_2SO_4, 10 per cent	8031	688	11577	660	11597	409	11265	280	11460	377
38	NaOH, 5 per cent	5802	594	8685	905	9965	920	8515	920	7383	768
	(b) 14 days in water before immersion.										
6	Sol. 4, Na_2SO_4, 5 per cent	10815	638	9342	669	5503	297	4415	655	5050	455
7	Sol. 1, NaCl, 5 per cent	8950	525	8597	905	10295	846	8030	762	....	....
8	Sol. 6, Na_2CO_3, 5 per cent	9663	662	10660	830	10327	717	9907	720	10393	685
9	Sol. 7, $NaHCO_3$, 5 per cent	9453	423	8942	847	8882	757	9750	729	12270	712
12	Sol. 8, NaCl, 7 per cent	11700	437	9922	779	11390	948	10217	892	9503	793
	(c) 14 days in water and 3 months in air before immersion.										
10	Sol. 8, NaCl, 1 per cent	5791	771	8740	619	9215	749	8505	640	7950	593
11	Sol. 6, Na_2CO_3, 5 per cent	10467	712	11540	701	....	....	11235	672	10633	550
	(3) Neat Ideal in solutions of mixed salts.										
	(a) 7 days in water before immersion.										
17	Sol. 11, $CaCl_2$, $MgCl_2$, NaCl, 1.33 per cent each	5723	400	7837	336	8860	844	7960	797	8703	672
16	Sol. 10, NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$, 1.25 per cent each	8552	337	11167	802	8300	849	8120	745	7850	773
	(b) 3 months in water before immersion.										
14	Sol. 10 (See No. 16)	7090	455	10355	916	7680	794	8085	807	7553	860
	(c) 48 hours in damp oven before immersion.										
33	Sol. 10, NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$, 1.25 per cent each	4035	340	10440	297	9880	1105	7325	1131	7920	1175

TABLE II—(Continued).

Lab. No.	SOLUTION	Before immersion		After being in solution:							
				12 months		24 months		30 months		40 months	
		Compress.	Tension	Compress.	Tension	Compress.	Tension	Compress.	Tension	Compress.	Tension
	(4) Neat Ideal to show effects of titration.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
37	In water. Titrated with H_2SO_4*	5288	326	9622	726	10165	667	10650	679	10640	255
43	Sol. 14, NaCl, Na_2SO_4, 2.5 per cent each. Titrated weekly†	7162	261	12570	581	11330	876	10827	720	10020	980
39	In water. Titrated daily‡	4760	387	10240	475	10565	836	12100	821	10607	805
45	Sol. 4, Na_2SO_4, 5 per cent. Titrated weekly§	6174	276	10522	902	9885	804	9287	860	9660	740
	II. Mortars of Ideal in various ratios:										
	(1) 1:1 mortar.										
	(a) In distilled water for comparison.										
46	In distilled water	6457	634	9987	571	8472	766	10232	756	8852	740
	(b) In solutions of mixed salts.										
23	Sol. 10, NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$, 1.25 per cent each	7118	661	6160	816	5278	571	4517	702	3350	633
22	Sol. 12, NaCl, Na_2CO_3, Na_2SO_4, 1.66 per cent each	8165	693	8270	844	10202	800	9265	877	10457	905
49	Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each‖	4505	588	8760	861	8445	916	9480	882	8973	843
	(2) 1:2 mortars in mixed salts.										
26	Sol 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	4252	557	5985	453	5970	501	4662	470	4497	213
36	Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	3487	301	4315	370	5732	429	4262	509	4244	480
	(3) 1:3 mortars in mixed salts.										
21	Sol. 10, NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$, 1.25 per cent each	2528	535	1672	349	Could	be er	ushed	by	hand	
27	Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	2404	456	2504	519	2807	586	2732	521	3370	550
20	NaCl, Na_2SO_4, 2.5 per cent each	3753	409	6022	406	4987	395	5440	397	5500	297

*Titrated daily; water changed weekly.
†Titrated once a week; solution not changed.
‡Titrated daily; water changed after each test for strength.
§Titrated weekly; water changed after each test for strength.
‖Atlas cement; in water 30 days.

TABLE II—(Continued).

Lab. No.	SOLUTION	Before immersion		After being in solution: 12 months		24 months		30 months		40 months	
		Compress	Tension	Compress	Tension	Compress	Tension	Compress	Tension	Compress	Tension
	III. So-called alkali-proof cements:	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
	(1) Neat alkali-proof in various solutions.										
13	"Alkali-proof." Sol. 9, NaCl, Na_2CO_3, 1 per cent each; Na_2SO_4, 3 per cent*	8905	596	9802	575	11407	492	10575	545	10003	592
60	"Alkali-proof." Sol. 2, $MgSo_4$, 5 per cent	3735	352	8038	996	10192	1021	8350	931	...	...
	(2) 1:1 mortars in solutions of mixed salts.										
40	"Iron ore." Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	3256	426	7802	859	10425	959	10247	989	11057	905
50	"Iron ore." Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each†	4032	522	9172	874	9952	930	10717	936	9387	995
44	"Apple." Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	4157	471	8950	812	9370	859	10137	800	10037	740
51	"Alkali-proof." Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each†	4095	552	5955	766	7935	875	7125	852	7247	760
	IV. Cements with chemicals added to the water in mixing:										
	(1) Neat Ideal in solutions of mixed salts.										
18	Mixed in 1 per cent H_2SO_4. Sol. 12, NaCl, Na_2CO_3, Na_2SO_4, 1.66 per cent each	9774	636	8867	565	9667	755	10547	749	10633	748
19	Mixed in 1 per cent $(NH_4)_2SO_4$. Sol. 12, NaCl, Na_2CO_3, Na_2SO_4, 1.66 per cent each	7706	455	9952	674	11765	847	8942	869	9510	840
	(2) 1:1 mortars in solutions of mixed salts.										
24	Mixed in 5 per cent H_2SO_4. Sol. 13 (See Sol. 13 above)	6752	662	7330	509	9265	862	8565	867	9080	965
29	Mixed in 1 per cent H_2SO_4. Sol. 13 (See Sol. 13 above)	7320	695	7632	725	8772	806	8685	829	7673	827
28	Mixed in 1 per cent H_2SO_4 and 1 per cent Na_2HPO_4 Sol. 13 (See Sol. 13 above)	5967	656	7705	815	7777	807	8495	779	8593	893
54	Mixed in 1 per cent H_2SO_4. Sol. 13 (See Sol. 13 above)	3476	488	9362	874	9729	967	10157	872	9717	910

*4 months in water before immersion.
†30 days in water before immersion.

The changes in strength are not very great, but they are rather characteristic. One of the facts made apparent by the data from the strength tests is that immersion in solutions of alkali salts does not interfere with the setting of either neat cement or mortars. Even cements which were in water as long as three months previous to immersion in the solutions, and were supposed to have reached practically the limit of strength, showed a marked increase of strength after the first period in solution. (See No. 11 and No. 12.) In some cases the changes in tension and compression strength did not have the same sign. The writer has no explanation for this phenomenon. As a measure of the change of strength during the periods, the mean of the change tension and compression was taken, and is shown in Table III.

In all cases, except two, where comparison was possible, there was a period where the cements in solutions were as strong or even stronger than similar cement kept in distilled water during the same period. For these comparisons the mean of the tension and compression strength is taken, as compared to the strength of cement originally put in distilled water. These comparisons are shown in Table IV.

III. Discussion of the Data.

Theories Concerning Change in Molecular Volume.—The decrease in the strength of cement that has been subjected to the action of alkali is ascribed by some experimenters to changes of volume. The chief reacting substance in the cement is lime, in the form of calcium hydroxide. With the sulphate salts of sodium and magnesium it forms calcium sulphate ($CaSO_4.2H_2O$) and sodium hydroxide with the former and calcium sulphate and magnesium hydroxide with the latter. The ratio of the molecular volume of calcium hydroxide to the molecular volume of calcium sulphate formed in the reaction is as 1 :1, 98. The sodium hydroxide formed in the reaction stays in solution. In the case of magnesium sulphate the ratio of the molecular volume of the calcium hydrox-

TABLE III—*Showing Change of Strength of Cement Blocks During a Period in Salt Solutions Expressed as Per Cent, Computed on the Strength of the Green Cement at the Last Preceding Test.*

Lab. No.	SOLUTION	After being in solution: 12 months Comp.	12 months Tens'n	12 months Ave.	24 months Comp.	24 months Tens'n	24 months Ave.	30 months Comp.	30 months Tens'n	30 months Ave.	40 months Comp.	40 months Tens'n	40 months Ave.
		%	%	%	%	%	%	%	%	%	%	%	%
	I. Neat Ideal in various solutions:												
	(1) In distilled water for comparison.												
15	Distilled water	—8.7	+44.8	+18.0	+35.1	+4.0	+19.5	+14.1	—3.1	+2.4	—20.2	+0.1	—10.0
	(2) In solutions of single salts.												
	(a) 7 days in water before immersion.												
1	Sol. 1, NaCl, 5 per cent	+43.4	+250.0	+146.7	+5.2	+2.3	+3.7	+2.6	—10.5	—3.9	—27.9	—16.8	—22.3
2	Sol. 2, $MgSO_4$, 5 per cent	+46.3	—27.8	+9.2	—2.6	—40.0	—21.3	—11.2	+125.2	+57.0	—19.5	—5.9	—20.9
3	Sol. 3, Na_2SO_4, 1 per cent	+21.0	—12.0	+5.5	+0.2	+101.0	+50.6	—4.0	—10.0	—7.0	—11.9	—3.7	—7.8
4	Sol. 4, Na_2SO_4, 5 per cent	+9.7	+9.5	+9.6	—16.6	+11.1	—2.7	—7.9	—2.0	—4.9	+0.6	—9.8	—4.6
5	Sol. 5, Na_2SO_4, 10 per cent	+44.1	—4.0	+20.0	+0.2	—38.0	—18.9	—2.8	—31.5	—17.1	—7.1	+34.6	+13.7
38	5 per cent NaOH	+49.6	+52.3	+50.9	+14.7	+1.5	+8.1	—1.5	0	—2.2	—15.3	—16.5	—15.9
	(b) 14 days in water before immersion.												
6	Sol. 4, Na_2SO_4, 5 per cent	—13.6	+4.8	—4.4	—41.1	—55.6	—48.3	—19.7	+123.9	+52.1	+14.3	—30.5	—8.1
7	Sol. 1, NaCl, 5 per cent	—3.9	+72.3	+34.2	+19.7	—6.5	+6.6	—22.0	—9.9	—15.8	....	....	....
8	Sol. 6, Na_2CO_3	+10.3	+25.3	+17.8	—3.1	—13.6	—8.3	—4.0	+0.4	—1.8	+4.9	—4.8	0
9	Sol. 7, $NaHCO_3$, 5 per cent	—5.4	+100.2	+47.4	—0.6	—10.6	—5.6	+9.7	—3.7	+3.0	+25.8	—2.3	+11.7
12	Sol. 8, NaCl, 1 per cent	—15.1	+78.2	+31.5	+14.7	+21.6	+18.6	—10.2	—5.9	—8.0	—3.9	—11.1	—9.0
	(c) 14 days in water and 3 months in air before immersion.												
10	Sol. 8, NaCl, 1 per cent	+50.9	—20.0	+15.4	+5.4	+21.0	+13.2	—7.7	—14.5	—11.1	—6.5	—7.3	—6.9
11	Sol. 6, Na_2CO_3, 5 per cent	+20.2	—1.5	+9.3	....	....	....	—2.6	—4.1	—3.3	—5.3	—18.1	—11.7

TABLE III—(Continued).

Lab. No.	SOLUTION	After being in solution: 12 months			24 months			30 months			40 months		
		Comp.	Tens'n	Ave.	Comp.	Tens'n	Ave.	Comp.	Tens'n	Ave.	Comp.	Tens'n	Ave.
		%	%	%	%	%	%	%	%	%	%	%	%
	(3) Neat Ideal in solutions of mixed salts.												
	(a) 7 days in water before immersion.												
17	Sol. 11, $CaCl_2$, $MgCl_2$, NaCl, 1.33 per cent each	+36.9	−16.0	+10.4	+13.0	+151.1	+82.0	−10.0	−5.5	−11.8	+8.5	−15.6	−3.5
16	Sol. 10, NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$, 1.25 per cent each	+30.5	+137.9	+84.2	−25.6	−5.8	−9.9	−2.1	−12.2	−7.7	−3.3	+3.7	+0.2
	(b) 3 months in water before immersion.												
14	Sol. 10, NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$, 1.25 per cent each	+46.5	+101.3	+73.9	−25.7	−13.3	−19.5	+5.2	+1.6	+3.4	−6.5	+6.5	0
	(c) 48 hours in damp oven before immersion.												
33	Sol. 10, NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$, 1.25 per cent each	+158.7	−12.3	+73.2	−5.3	+272.0	+133.3	−5.6	+2.3	−1.6	+8.1	+3.9	+6.0
	(4) Neat Ideal to show effects of titration.												
37	In water. Titrated with H_2SO_4*	+81.9	+133.7	+107.8	+5.6	−12.4	−3.9	+4.7	+1.7	+3.2	−0.1	−62.4	−31.2
43	Sol 14, NaCl, Na_2SO_4, 2.5 per cent each. Titrated weekly†	+74.6	+122.3	+98.4	−9.4	+50.7	+20.6	−4.4	−17.8	−11.1	−7.4	+22.2	+7.4
39	In water. Titrated daily‡	+115.1	+22.7	+68.9	+3.1	+76.0	+34.5	+14.4	−1.7	+6.3	−12.3	−1.9	−7.1
45	Sol. 4, Na_2SO_4, 5 per cent. Titrated weekly§	+70.3	+226.8	+148.5	−6.0	−10.8	−8.4	−6.0	+6.9	+0.4	+4.0	−13.9	−4.9

*Titrated daily; water changed weekly.
†Water not changed.
‡Water changed after each test for strength.
§Water changed after each test for strength.

Table III—(Continued).

Lab. No.	SOLUTION	After being in solution: 12 months Comp.	12 months Tens'n	12 months Ave.	24 months Comp.	24 months Tens'n	24 months Ave.	30 months Comp.	30 months Tens'n	30 months Ave.	40 months Comp.	40 months Tens'n	40 months Ave.
		%	%	%	%	%	%	%	%	%	%	%	%
	II. Mortars of Ideal in various solutions:												
	(1) 1:1 mortars.												
	(a) In distilled water for comparison.												
46	In distilled water......................	+54.6	+31.5	+43.0	—15.1	+34.1	+9.5	+20.7	—1.3	+9.7	—13.4	—2.1	—7.7
	(b) In solutions of mixed salts.												
23	Sol. 10, NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$, 1.25 per cent each	—12.0	+23.4	+5.7	—14.3	—30.0	—22.1	—14.4	+22.9	+4.2	—25.9	—9.8	—17.8
22	Sol. 12, NaCl, Na_2CO_3, NA_2SO_4, 1.66 per cent each	+1.2	+21.8	+11.5	+18.9	—5.2	+16.8	—9.1	+9.6	+0.2	+12.8	+3.1	+7.9
49	Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each*	+94.4	+46.4	+70.4	—3.5	+6.3	+1.4	+12.2	—3.6	+4.3	—5.3	—4.4	—4.8
	(2) 1:2 mortars in mixed salts.												
26	Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each..	+40.7	—18.6	+11.0	—0.2	+10.3	+5.1	—21.9	—6.1	—14.0	—3.5	—54.6	—29.0
36	Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each..	+23.7	+22.5	+23.1	+32.8	+15.9	+24.3	—25.6	+18.4	—3.6	—0.4	—5.7	—3.5
	(3) 1:3 mortars in mixed salts.												
21	Sol. 10, NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$, 1.25 per cent each	—37.8	—34.7	—36.2	Could	be crus	hed by	hand					
27	Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each..	+4.1	+15.8	+9.9	+12.1	+12.9	+12.5	—2.6	—11.0	—8.8	+23.3	+5.5	+14.4
20	Sol. 12, NaCl, Na_2CO_3, Na_2SO_4, 1.66 per cent each	+60.1	—0.7	+28.7	—17.2	—2.7	—9.9	+9.0	+0.5	+4.7	+1.1	—25.1	—12.0

*Atlas; 30 days in water.

TABLE III—(Continued).

Lab. No.	SOLUTION	After being in solution:											
		12 months			24 months			30 months			40 months		
		Comp.	Tens'n	Ave.	Comp.	Tens'n	Ave.	Comp.	Tens'n	Ave.	Comp.	Tens'n	Ave.
	III So-called alkali-proof cements:	%	%	%	%	%	%	%	%	%	%	%	%
	(1) Neat alkali-proof in various solutions.												
13	"Alkali-proof." Sol. 9, NaCl, Na_2CO_3, 1 per cent each; Na_2SO_4, 5 per cent*	+10.0	—3.5	+3.2	+16.3	—14.2	+1.0	—7.2	+10.7	+1.7	—5.4	+8.6	+1.6
60	"Alkali-proof." Sol. 2, $MgSO_4$, 5 per cent	+115.2	+182.9	+149.0	+25.5	+2.5	+14.0	—18.0	—8.8	—13.4			
	(2) 1:1 mortars in solutions of mixed salts.												
40	"Iron ore." Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	+139.0	+101.6	+120.3	+33.6	+11.6	+22.6	—1.7	+3.1	+0.7	+7.9	—8.4	—0.2
50	"Iron ore." Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each†	+127.4	+67.4	+97.4	+8.5	+6.4	+7.4	+7.7	+0.6	+4.1	—12.4	+6.3	—3.0
44	"Apple." Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	+115.2	+72.4	+93.8	+4.6	+5.7	+5.1	+8.1	—6.8	+1.3	—0.9	—7.5	—4.2
51	"Alkali-proof." Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each†	+45.4	+38.7	+42.0	+33.2	+14.2	+23.7	—10.2	—2.6	—6.4	+1.4	—10.7	—4.6

*4 months in water before immersion.
†30 days in water before immersion.

TABLE III—(Continued).

Lab. No.	SOLUTION	After being in solution: 12 months Comp.	12 months Tens'n	12 months Ave.	24 months Comp.	24 months Tens'n	24 months Ave.	30 months Comp.	30 months Tens'n	30 months Ave.	40 months Comp.	40 months Tens'n	40 months Ave.
		%	%	%	%	%	%	%	%	%	%	%	%
	IV. Cements with chemicals added to the water in mixing:												
	(1) Neat Ideal in solutions of mixed salts.												
18	Mixed in 1 per cent H_2SO_4. Sol. 12, NaCl, Na_2CO_3, Na_2SO_4, 1.66 per cent each	—9.2	—11.1	—10.1	+9.0	+33.6	+21.3	+9.1	+0.7	+4.2	+0.8	—0.1	+0.3
19	Mixed in 1 per cent $(NH_4)_2SO_4$. Sol. 12, NaCl, Na_2CO_3, Na_2SO_4, 1.66 per cent each	+29.0	+48.1	+38.5	+18.2	+25.8	+22.0	—23.9	+2.5	—10.7	+6.3	—3.3	+1.5
	(2) 1:1 mortars in solutions of mixed salts.												
24	Mixed in 5 per cent H_2SO_4. Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	+8.6	—23.1	—7.2	+26.4	+69.3	+42.8	—7.6	+0.5	—3.5	+6.0	+11.3	+8.6
29	Mixed in 1 per cent H_2SO_4, Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	+4.2	+4.3	+4.2	+14.9	+11.1	+13.0	—0.9	+2.8	+0.9	—11.6	—0.2	—5.9
28	Mixed in 1 per cent H_2SO_4 and 1 per cent Na_2HPO_4. Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	+29.1	+24.2	+26.5	+1.0	—1.0	0	+9.2	—2.2	+3.5	+1.0	+14.6	+7.8
54	Mixed in 1 per cent H_2SO_4. Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	+163.5	+79.1	+121.3	+3.8	+10.6	+7.2	+4.4	—9.8	—2.2	—4.3	+4.3	0

TABLE IV—*Showing the Strength of Cement Blocks Before and After Given Periods in Salt Solutions Expressed as Per Cent of the Strength of Cement Blocks in Water for a Similar Length of Time.*

Lab. No.	SOLUTION	Before Immersion			After being in solution: 12 months			24 months			30 months			40 months		
		Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
	I. Neat Ideal in various solutions:															
	(1) In distilled water for comparison.															
15	Neat Ideal. In distilled water	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	(2) In solutions of single salts.															
	(a) 7 days in water before immersion.															
1	Sol. 1, NaCl, 5 per cent	86.1	57.4	71.7	135.4	138.8	137.1	106.5	136.5	121.5	95.8	134.4	115.1	76.2	110.1	93.1
2	Sol. 2, $MgSO_4$, 5 per cent	101.4	134.4	117.9	162.5	67.3	114.9	118.3	38.7	78.5	91.9	96.1	94.0	81.7	90.2	85.9
3	Sol. 3, Na_2SO_4, 1 per cent	112.7	92.1	102.4	149.5	55.8	102.6	112.0	108.1	110.0	94.2	107.0	100.6	91.6	102.9	97.2
4	Sol. 4, Na_2SO_4, 5 per cent	98.4	119.0	108.7	118.0	89.9	103.9	73.6	96.1	84.9	59.4	103.5	81.4	66.0	93.1	79.5
5	Sol. 5, Na_2SO_4, 10 per cent	102.6	139.2	120.9	162.2	92.1	127.1	121.3	54.9	83.1	103.2	41.3	72.2	105.8	55.6	80.7
38	N. I., 5 per cent NaOH	74.1	120.2	97.1	121.5	126.3	123.9	104.2	123.4	113.8	80.8	35.8	103.3	74.7	113.2	93.1
	(b) 14 days in water before immersion.															
6	Sol. 4, Na_2SO_4, 5 per cent	138.1	129.1	133.6	130.7	93.4	112.0	57.5	39.8	48.6	40.5	96.7	68.6	51.1	67.1	59.1
7	Sol. 1, NaCl, 5 per cent	114.2	106.3	110.2	120.3	126.3	122.3	107.7	113.5	110.6	73.6	112.5	93.0	....	....	....
8	Sol. 6, Na_2CO_3, 5 per cent	123.5	134.0	128.8	149.2	115.9	132.5	108.0	96.2	102.1	90.8	106.3	98.5	105.2	100.2	102.6
9	Sol. 7, $NaHCO_3$, 5 per cent	120.8	85.6	108.2	125.4	118.2	121.8	92.9	101.6	97.2	89.3	107.6	98.4	124.2	105.0	114.6
12	Sol. 8, NaCl, 1 per cent	149.5	95.7	122.6	138.8	108.8	123.8	119.1	127.2	123.1	93.6	131.7	112.6	96.2	116.9	106.5
	(c) 14 days in water and 3 months in air before immersion.															
10	Sol. 8, NaCl, 1 per cent	74.0	156.7	115.3	122.3	186.4	104.3	96.3	100.5	98.4	77.9	94.5	86.2	80.4	87.4	83.7
11	Sol. 6, Na_2CO_3, 1 per cent	133.7	144.1	138.9	161.5	97.8	129.6	....	....	....	103.0	99.2	101.1	107.6	81.1	94.3

TABLE IV—(Continued).

Lab. No.	SOLUTION	Before Immersion			After being in solution: 12 months			24 months			30 months			40 months		
		Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
	(3) Neat Ideal in solutions of mixed salts.															
	(a) 7 days in water before immersion.															
17	Sol. 11, $CaCl_2$, $MgCl_2$, NaCl, 1.33 per cent each	73.1	81.0	77.0	109.6	46.9	78.2	92.6	111.9	102.2	72.9	117.7	95.3	88.1	99.1	93.6
16	Sol. 10, NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$, 1.25 per cent each..	109.3	68.2	88.7	156.1	112.0	134.0	86.9	113.9	100.4	74.4	110.0	92.2	79.4	114.0	96.7
	(b) 3 months in water before immersion.															
14	Sol. 10, NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$, 1.25 per cent each..	90.6	92.1	91.3	144.9	127.9	136.4	80.3	106.5	93.4	74.1	119.2	91.6	76.4	126.8	101.6
	(c) 48 hours in damp oven before immersion.															
33	Sol. 10, NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$, 1.25 per cent each..	51.6	68.8	60.2	116.1	41.4	93.7	103.3	148.3	120.8	67.1	167.0	117.0	80.1	174.7	122.4
	(4) Neat Ideal to show effects of titration.															
37	In water. Titrated daily with H_2SO_4,*	65.0	66.0	65.5	134.6	101.3	117.9	106.3	89.5	97.9	97.1	102.2	98.6	107.7	37.6	72.6
43	Sol. 14. NaCl, Na_2SO_4, 2.5 per cent each. Titrated weekly with H_2SO_4†	91.5	52.8	72.1	175.0	81.1	123.0	118.5	117.5	118.0	99.3	106.3	102.3	101.4	144.5	122.9
39	In water. Titrated daily with H_2SO_4‡	68.2	78.3	73.2	143.3	66.2	104.7	101.5	112.2	111.3	110.9	121.2	116.0	107.3	118.7	113.0
45	Sol 4, Na_2SO_4, 5 per cent. Titrated weekly with H_2SO_4‡	78.8	55.8	67.3	147.1	125.9	136.5	103.3	107.9	105.6	84.3	127.0	105.6	97.8	109.1	103.4

*Water changed weekly. †Solntion not changed. ‡Water changed after each test for strength.

TABLE IV—(Continued).

Lab. No.	SOLUTION	Before Immersion			After being in solution: 12 months			24 months			30 months			40 months		
		Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
	II. Mortars of Ideal in various ratios:															
	(1) 1:1 mortar.															
	(a) In distilled water for comparison.															
46	In distilled water	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	(b) In solutions of mixed salts.															
23	Sol. 10, NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$, 1.25 per cent each	110.2	152.3	131.2	61.6	142.9	102.2	62.2	74.5	68.3	44.1	92.8	68.4	37.8	85.5	61.6
22	Sol. 12, NaCl, Na_2CO_3, Na_2SO_4, 1.66 per cent each	126.4	159.6	143.0	82.8	147.8	115.5	120.5	104.4	112.4	90.5	116.0	103.2	118.1	122.3	120.7
49	Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each*	69.7	135.4	102.5	87.7	150.7	119.2	99.6	119.5	109.5	92.6	116.6	104.6	101.3	113.9	107.6
	III. So-called alkali-proof cements:†															
	(1) Neat alkali-proof in variois solutions.															
13	"Alkali-proof." Sol. 9, NaCl, Na_2CO_3, 1 per cent each; $NaSO_4$, 5 per cent‡	113.8	120.6	117.2	137.2	80.3	108.7	119.2	66.0	92.6	96.9	80.5	88.7	101.2	87.3	94.2
60	"Alkali-proof." Sol. 2, $MgSO_4$, 5 per cent	47.7	71.2	59.4	112.3	139.1	125.7	106.6	137.0	121.8	76.5	137.3	106.9	....	....	....

*Atlas cement; in water 30 days.
†Compared with Ideal cement. No comparison for 1:2 and 1:3 mortars.
‡4 months in water before immersion.

TABLE IV—(Continued).

Lab. No.	SOLUTION	Before immersion			After being in solution:											
					12 months			24 months			30 months			40 months		
		Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
	(2) 1:1 mortars in mixed solutions.															
40	"Iron ore." Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	50.4	98.1	74.2	78.1	150.4	114.2	123.0	125.1	124.0	100.1	130.8	115.4	124.8	122.3	123.5
50	"Iron ore." Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each*	62.4	120.2	91.3	91.8	153.0	122.4	117.4	121.4	119.4	104.7	123.8	114.2	106.2	134.4	120.3
44	"Apple." Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	64.3	108.5	86.4	89.6	142.2	115.9	110.5	112.1	111.3	99.0	105.5	102.2	113.3	100.0	106.6
51	"Alkali-proof." Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each*	63.4	127.1	95.2	59.6	134.1	96.8	93.6	114.2	103.9	69.6	112.6	91.1	81.8	102.7	91.7
	IV. Cements with chemicals added to the water in mixing:															
	(1) Neat Ideal in solutions of mixed salts.															
18	Mixed with 1 per cent H_2SO_4. Sol. 12, NaCl, Na_2CO_3, Na_2SO_4, 1.66 per cent each	124.9	128.7	126.8	124.1	78.9	101.5	101.1	101.3	101.2	96.9	110.6	103.7	107.4	110.4	108.9
19	N. I. mixed in 1 per cent $(NH_4)_2SO_4$. Sol. 12, NaCl, Na_2CO_3, Na_2SO_4, 1.66 per cent each	98.5	92.1	95.3	139.2	94.1	116.6	123.0	113.6	118.3	81.9	128.3	105.1	96.2	123.8	108.2
	(2) 1:1 mortars in solutions of mixed salts.															
24	Mixed with 5 per cent H_2SO_4. Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each	104.5	152.5	128.5	73.3	89.1	81.2	109.3	112.5	110.9	83.7	114.6	99.1	102.5	130.4	116.4

*30 days in water before immersion.

TABLE IV—(Continued).

Lab. No.	SOLUTION	Before Immersion			After being in solution:											
					12 months			24 months			30 months			40 months		
		Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average	Comp.	Tension	Average
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
29	Mixed with 1 per cent H_2SO_4. Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each......	111.8	160.1	135.9	76.4	126.9	101.6	103.5	105.2	104.3	84.8	109.6	97.2	86.6	111.7	99.1
28	Mixed with 1 per cent H_2SO_4+ 1 per cent Na_2HPO_4. Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each........................	92.4	152.2	123.3	76.1	142.7	109.4	91.7	105.3	98.5	83.1	103.0	93.0	96.7	120.6	108.6
54	Mixed with 1 per cent H_2SO_4. Sol. 13, NaCl, Na_2CO_3, Na_2SO_4, 3 per cent each......	53.8	112.4	83.1	93.7	153.0	123.3	114.7	126.2	120.4	99.2	115.3	107.2	109.7	122.9	116.3

ide originally in the set cement to the molecular volume of calcium sulphate and magnesium hydroxide formed in the reaction is as 1:2, 78. The disintegration of cement is ascribed as being due to this formation of compounds with larger molecular volumes, causing expansion and consequent cracking. (Bulletin 81 of the Montana Experiment Station.). Another theory, similar to the above, is held by several experimenters. According to this theory, tricalcium-sulpho-aluminate is formed and this then causes the expansion and disintegration of cement. In *Technologic Paper No. 12* of the Bureau of Standards, by Messrs. Bates, Phillips, and Wig, it has been conclusively proved tnat this compound is not and could not be formed.

Of the neat cement at the end of 40 months, set No. 6, in 5 per cent Na_2SO_4 solution, had the lowest strength: 59.1 per cent of the strength of cement in water. This set was 14 days in water previous to immersion in the solution. Another set, No. 4, which was 7 days in water previous to immersion in the solution, had the next lowest strength: 79.5 per cent. Set 5, 14 days in water, in 10 per cent sodium sulphate solution, had 80 per cent of the strength of cement in water. Thus it appears that the sodium sulphate solution was the most injurious, since all the sets immersed in it had low strength.

The cement in 5 per cent magnesium sulphate solution had only 85.9 per cent strength, showing that it also was injurious, although not in as high degree as the 5 per cent sodium sulphate solution. Yet, according to the change-of-volume theory, the magnesium sulphate solution ought to be the more injurious of the two. For, according to this theory, when the cement is acted upon by the sodium sulphate solution, the ratio of the volume of the insoluble product formed in place of the calcium hydroxide originally in the cement, to the volume of the corresponding product formed by the action of the magnesium sulphate solution is as 1.98 to 2.78.

Experiments to Test Change-of-Volume Theories.—In order to test whether or not the larger molecular volume re-

spectively of $CaSO4, 2H_2O$ and $CaSo_42H_2O+Mg(OH)_2$ in place of the $Ca(OH)_2$ was the cause of disintegration, the following experiment was conducted:

The sodium hydroxide formed in the reaction between $Ca(OH)_2$ and Na_2SO_4 was neutralized daily with sulphuric acid. When no further alkaline reaction took place, it was assumed that all the calcium hydroxide had been reacted upon, and consequently the maximum amount of calcium sulphate had been formed. At this time, according to the theory, the cement should have been the weakest. Figure 7 represents the

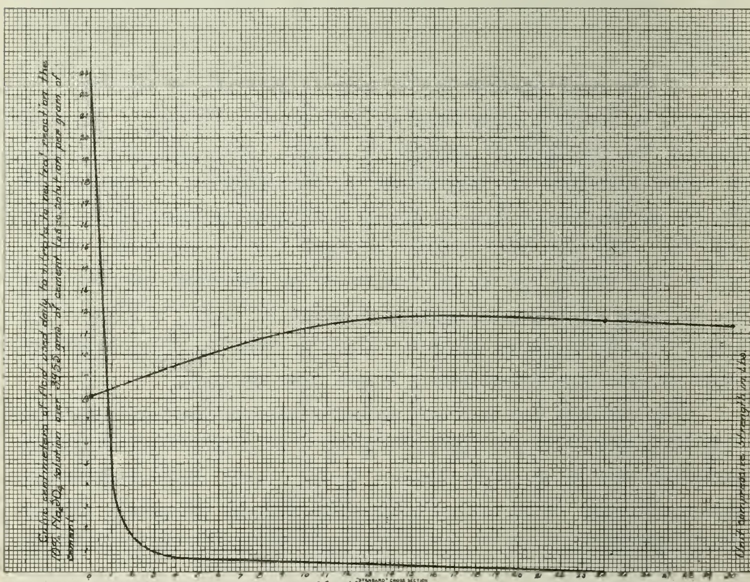

Fig. 7.

results graphically. After 24 months, the time when the reaction in question had just been completed, the compression strength of the cement was practically at it highest point.

Figure 11 shows the effects caused by changes of volume, which were obtained in a mixture of one part of underburned

Fig. 11.

cement to two parts of standard sand. If changes of volume were produced and were the cause of disintegration of cement in alkali solutions, then cracking somewhat similar to that shown in the figure should appear in some other set out of the sixty used in the experiment.

Out of all the sets used in the experiments No. 21, the only cement that was completely disintegrated, was a mortar of one part of cement to three parts of sand. It was in a solution of chlorides and sulphates of sodium and magnesium. If disintegration is caused by expansion or contraction, there should not be such a striking difference between neat cement and a 1:3 mortar.

Lime Content and Strength.—A comparison of the srength of sets No. 7 and No. 12 shows that the 5 per cent sodium chloride solution was more injurious than the 1 per cent solution. The analyses of the cements in these solutions show that the lime content of cement in the 5 per cent sodium chloride solution is less than the line content of cement in the 1 per cent sodium chloride solution. The analyses of the solutions gave the following amounts of CaO per 100 cc. of solution:

100 cc. of 5 per cent solution of NaCl contained 0.1667 gram of CaO.

100 cc. of 1 per cent solution of NaCl contained 0.1106 gram of CaO.

So there is a difference of 0.0561 gram per 100 cc.

Since there was no noticeable difference in the chlorine content of the cement in these two solutions, it might be assumed that the amount of the chlorine-containing compound formed in the cement was the same in the two solutions of different strength.

Effect of Not Changing the Solution and Titrating With Acid.—As already stated, the change of strength usually is such that the cement increases in strength up to the maximum and after that there is a slow decrease. The highest point usually is as high as, or somewhat higher, than the highest point of cement in distilled water. The only sets where neither the tensile nor compression strength ever became as high as that of cement in water, are sets 4 and 6, both in 5 per cent sodium sulphate solution. Set No. 45, also in 5 per cent sodium sulphate solution which was never changed, but which titrated to neutrality once a week with sulphuric acid, had an average strength after 40 months of 103.4 per cent of the strength of cement in water. Set No. 39 was put in distilled water and, afterwards, sulphuric acid was added daily to slightly acid reaction. This cement had 113.0 per cent strength.

The appearance of cement No. 39 and No. 45 was perfectly sound—cubes as well as briquettes. The corners were

as sharp as before and no swelling or warping was observed. Figure 8 shows the appearance of cement briquettes and cubes from set No. 4. Figure 9 shows how layers of cement are successively falling off.

FIG. 8.

Cementing Effect of Calcium Sulphate.—In sulphate solutions the comparison of the relative effects of solutions of different concentration is rather difficult. The formation of calcium sulphate seems to increase the strength of cement, for it acts as a cementing medium. This fact was more clearly demonstrated when two halves of a briquette were put close together in sodium sulphate solution, and after four months it

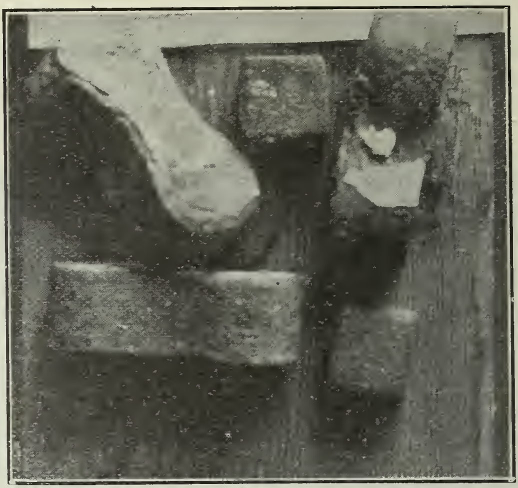

Fig. 9.

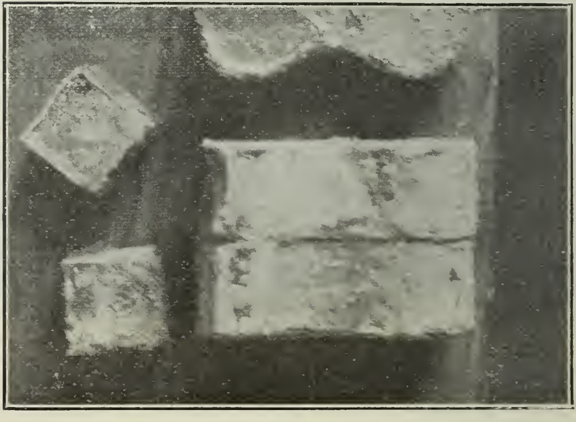

Fig. 10.

took a force of 245 pounds to pull them apart. Figure 10 shows how two briquettes were cemented together. When pulled apart, the inside surfaces were found to be covered with amorphous and crystalline calcium sulphate. Another pair of

halves was put in distilled water, and there no cohesion was observed.

Decrease of Strength Caused by Solvent Action.

The factor with the tendency to decrease the strength of cement is the solvent action of the solution. That the solvent action must have a noticeable influence is evident from sets No 39 and No. 45, in which the solution never was changed.

The solubility of $CaSO_4$ in a 1 per cent sodium sulphate solution is very nearly the same as in a 5 per cent sodium hydroxide solution. The comparison of sets No. 3 and No. 6 shows that at the end of 40 months the strength was nearly the same:

Compression, 10,712 and 10,815.

Tension, 806 and 688.

The solvent effect of solutions of alkali salts was tested with small qualities of cement, which were agitated with large volumes of solutions. The cement had not been treated with water for setting. As much as 62.4 per cent of the lime and 58.6 per cent of SiO_2 was leached out by sodium sulphate solution.

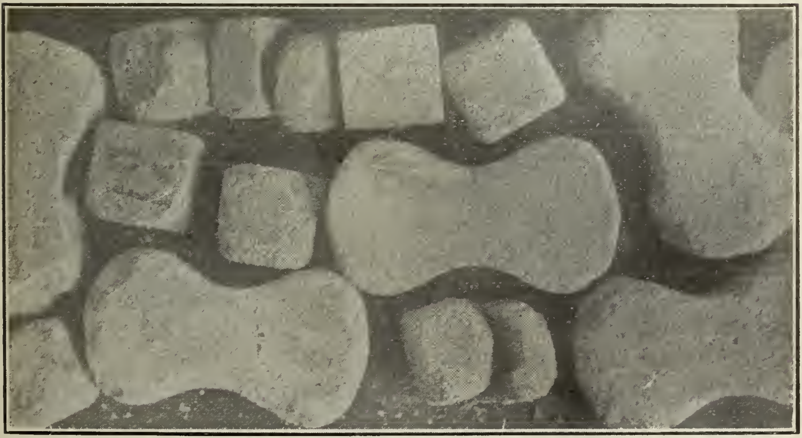

Fig. 17.

The rather slow decrease of strength supports the assumption that the solvent action is the ultimate cause of disintegration. The gradual peeling off of layers also indicates that the effects are like those of a dissolving action. Figure 17 shows the effect that disintegration has on the appearance of 1:3 mortar. The mortar gradually crumbles, much the same as sandstone from which the cementing material is slowly being removed.

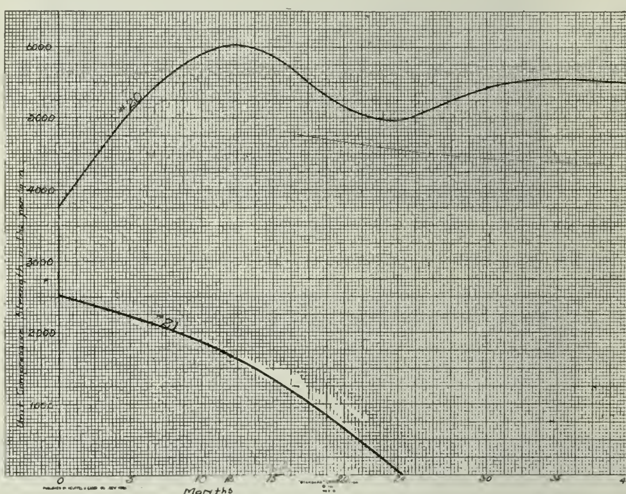

Fig. 12.

Carbonates Retard Solution.—Figure 12 shows diagrammatically a comparison of the effects of a solution containing carbonate with one not containing it. The mortar in the chloride-sulphate solution is completely disintegrated, while the mortar in the chloride-sulphate-carbonate solution has shown just a slight decrease. The sodium carbonate formed with calcium (the chief element of cement), a highly insoluble calcium carbonate, while the solubility of calcium sulphate in a chloride-sulphate solution is approximately 0.7 gram per 100 cc.

Increase of Solvent Action Caused by Sodium Hydroxide.—Since in the reaction with sodium sulphate, sodium hydroxide is formed, some cement (No. 38) was put in a 5 per cent sodium hydroxide solution. After the cement had reached its maximum strength, there was a regular decrease of strength of about 10 per cent during each period. The total strength changes as shown in Table IV were as follows: 97.1 per cent, 123.9 per cent, 113.8 per cent, 103.3 per cent, 93.9 per cent. Hence in the effects on cement produced in sodium sulphate solutions, the influence of sodium hydroxide must be also taken into consideration. This factor also enters when solutions of sodium carbonate are used.

Effect of Sodium Carbonate.—Solutions of sodium carbonate alone affect chiefly the silica of the cement and in a smaller degree the calcium. A small quantity of cement was leached with large volumes of sodium carbonate solution, after which the cement gave the following analysis:

> SoO_2, 8.54 per cent; Al_2O_3+Fe_2O3, 7.01 per cent; CaO, 46.22 per cent; MgO, 2.41 per cent; SO_3 0.20 per cent; Na_2O+K_2O, 3.2 per cent; CO_2, 32.01 per cent, and a trace of chlorine. (Compare analysis of set 15 in Table I.)

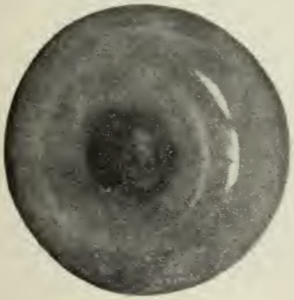

Fig. 13.

Fig. 14.

That the carbonate reacts with a bigger portion of cement than does the sulphate solution is shown in Figures 13 and 14.

Two small cakes of cement of equal weight were each put into a flask and treated with equal volumes of equivalent solutions of sodium carbonate and of sodium sulphate, respectively. The sodium carbonate (Figure 13) has reacted with nearly all of the cement, while the sodium sulphate (Figure 14) has reacted with but a small portion of it. The cake in Figure 13 is nearly all white from the calcium carbonate formed, while Figure 14 shows the natural cement color.

The change in the strength of cement in sodium carbonate solutions is not so great as in sodium sulphate solutions. The sodium carbonate reacts slowly; the calcium carbonate formed is very insoluble; the attack on silica is slight as long as there is unchanged calcium present; and supposedly the calcium carbonate formed, at least to some extent, acts as a cementing substance. This last conclusion may be drawn from the appearance of the cake in Figure 13. Although the appearance of the cement was entirely changed, it was still a strong mass, without showing apparent signs of weakening. In a 5 per cent sodium carbonate solution the strength changed as follows after the different periods: 132.5 per cent, 102.1 per cent, 98.5 per cent, 102.6 per cent. As might be expected, the decrease of strength in a 5 per cent sodium acid carbonate solution was more rapid, after the highest point was reached, viz.: 123.3 per cent, 110.6 per cent, 93 per cent.

Effect of Two or More Salts Combined.—Solutions containing chlorides, sulphates, and carbonates had a lesser weakening effect than the solutions containing only one salt. The combinations tried are not sufficient to decide which of these salts in the combination of three has a retarding influence, and which has an accelerating influence. Figure 15 shows graphically the effect of a sodium chloride-sulphate-carbonate solution upon the compression strength of a 1:1 mortar (upper curve) and the effect of a sodium chloride-sulphate solution upon a similar mortar (lower curve). Figure 16 shows the same for tensile strength. At the end of 40 months in the solution containing the carbonate the cement had not reached

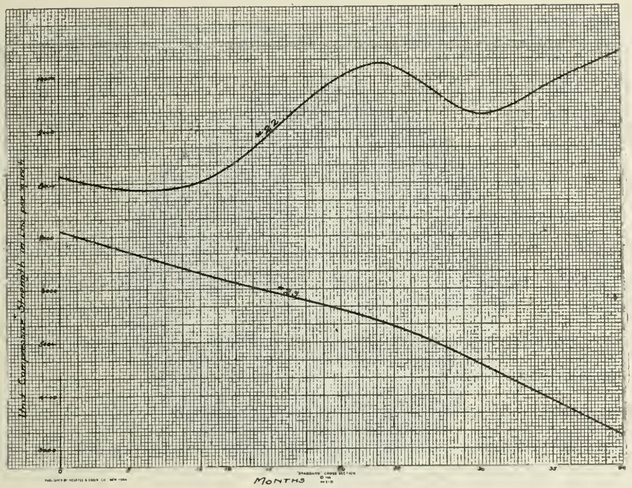

Fig. 15.

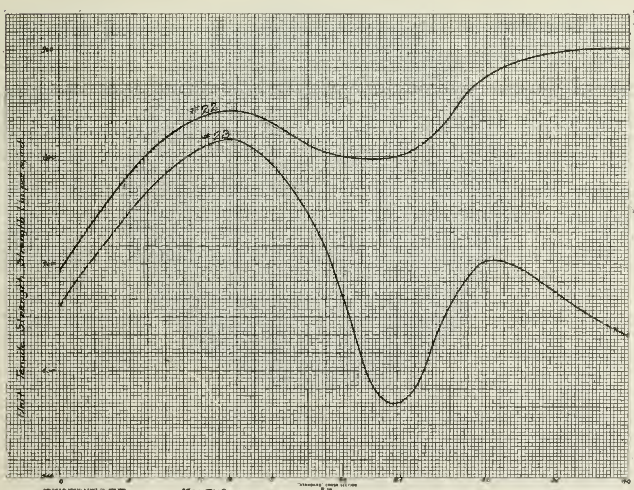

Fig. 16.

its maximum strength, while in the solution that contained no carbonate, a markeed decrease in strength had already occurred.

The cements mixed with varying strengths of sulphuric acid reached a high strength and kept it all during the time of the experiment. The cement which was mixed with 5 per cent acetic aldehyde (No. 35) reached a strength as high as normal, but it afterwards showed a rapid decrease in strength, which fact seems to indicate that organic substances in contact with cement may have a considerable influence.

Figure 18 is a microphotograph of cement from set No. 4, the weakest cement, from 5 per cent sodium sulphate solution, and Figure 19 shows set No. 45, the strongest cement, from 5 per cent sodium sulphate solution. There is no noticeable difference in appearance.

Probable Reactions.—The analyses in Table I seem to point to the conclusion that besides the reactions of the single salts with calcium hydroxide, there is also a change in the silicates as might be indicated by the variation of constitutional water. The increase of sodium content might be due to the formation of compounds identical or analogous to the one mentioned previously.

In solutions containing more than one salt, apparently other reactions, besides the ones mentioned before, take place, namely, reactions between reaction products and salts. Following are the reactions which very probably take place, judging from the effects upon the lime and silica contents in cement, which had been exposed to the action of different alkali salts:

1. $Ca(OH)_2+Na_2SO_4+aq.\rightarrow CaSO_4.2H_2O+2NaOH$ aq.
2. $Ca(OH)_2+MgSO_4+aq.\rightarrow CaSO_4.2H_4O+Mg(OH)_2+aq.$
3. $Ca(OH)_2+Na_2CO_3+aq.\rightarrow CaCO_3+2NaOH+aq.$
4. $CaCO_3+NaCl\rightarrow Na_2CO_3+CaCl_2.$
5. $CaCO_3+Na_2SO_4\rightarrow Na_2CO_3+CaSO_4.$
6. $CaSO_4+NaCl\rightarrow CaCl_2+Na_2SO_4.$
7. M silicate+$Na_2CO_3\rightarrow$sodium silicate+M carbonate.

Of these reactions, the first three take place rather rapidly. The last four reactions take place rather slowly and their effects might be called solvent effects. The degree of their action depends chiefly upon the relative proportions of reagents

and products, as these reactions (except the seventh) are reversible.

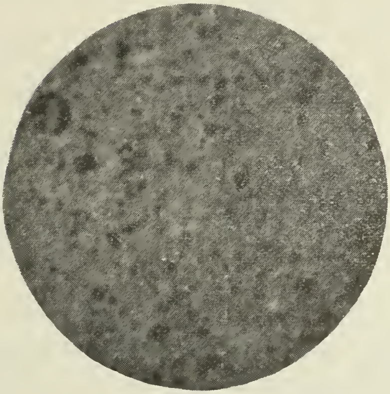

Fig. 18.

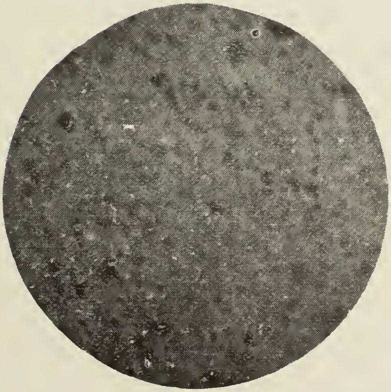

Fig. 19.

In these experiments the conditions have been such that the reversible reactions did not progress much towards the right. In other cases, where experimenters have used large quantities of solutions, complete disintegration has been obtained.

The results of the following experiment add support to the opinion that the first three reactions are not the cause of final and complete disintegration.

Neat "Ideal" cement was taken. It had been four years in water and had reached the following strength:

	Tension	*Compression*
	845	11,370
	840	11,170
		11,500
Average:	843	11,347

Two sets of this cement, composed of two briquettes and three cubes each, and weighing 396 grams a set, were heated for 50 hours on a water bath. One set was heated with distilled water, 2 cc. per gram of cement, and the other with saturated magnesium sulphate solution, also 2 cc. per gram of cement. The resulting strengths were as follows:

	—Tension—		*—Compression—*	
	A	*B*	*A*	*B*
	Cement in water	*Cement in saturated solution*		
	620	595	10,270	11,760
	570	615	9,130	10,560
			10,708	8,250
Averages:	595	605	10,060	10,157

Correspondingly the change of strength expressed in per cent was as follows:

—Tension—		*—Compression—*	
A	*B*	*A*	*B*
—29.4	—28.2	—11.3	—10.2

Table V—*Showing the Relation of the Content of Water of Constitution, Calcium, and Silica to the Strength of Cement, After Immersion in Salt Solutions.*

No. of set	Number of solution	Water of constitution	SiO_2	CaO	Strength compared with that of cement in water
		Per cent	Per cent	Per cent	Per cent
15	Distilled water (for comparison)	21.2	18.66	44.13	100
1	Sol. 1, 5 per cent NaCl	15.32	18.55	46.29	115
14	Sol. 10, 1.25 per cent each of NaCl, Na_2SO_4, $MgCl_2$ and $MgSO_4$	18.13	21.30	30.90	91
4	Sol. 4, 5 per cent Na_2SO_4	18.80	17.88	40.53	81
5	Sol. 5, 10 per cent Na_2SO_4	20.63	15.72	43.25	72
6	Sol. 4, 5 per cent Na_2SO_4	17.5	18.31	40.10	68

Relation of Silica or Lime Content to Strength.—Table V gives the strength of cement in solutions and the silica, calcium, and constitutional-water contents after 30 months in solution. Strength of cement in water=100. A comparison shows that in the cements which are below 100 in strength either the silica or lime content is lower than in cements that are 100 or above. In most cases the content of both lime and silica is lower. The analysis of No. 14 shows an example of the effect of the increased solvent action of NaCl upon the reaction product $CaSO_4.2H_3O$, the lime content being lower than in sets subject to the action of any of the other solutions.

SUMMARY.

1. Cement put in solutions of alkali salts sets as well as in water.

2. In solutions of sodium sulphate $CaSO_4.2H_2O$ is formed.

3. In solutions of magnesium sulphate $CaSO_4$, $2H_2O$, and $Mg(OH)_2$ are formed.

4. In solutions of sodium chloride a silicate is formed. The high percentage of sodium in this silicate is likely the reason for the increase of insoluble sodium in cement.

5. Sodium chloride in solution or its presence in solution with other alkali salts has its effect chiefly through a solvent action.

6. Of the solutions tested, the 5 per cent sodium sulphate solution had the greatest disintegrating effects.

7. Solutions containing chlorides, sulphates, and carbonates had the least effect.

8. Mortars disintegrate faster than neat cement.

9. The formation of compounds with molecular volumes larger than the molecular volume of calcium hydroxide is not the cause of disintegration of cement.

10. The ultimate cause of the disintegration of cement by alkalis is due to the alkalis forming compounds with the elements of cement, which subsequently are removed from the cement by solution.

APPENDIX.

Lab. No.	CEMENT AND SOLUTION	Before immersion		After being in solution:							
				12 months		24 months		30 months		40 months	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	Ideal neat, in 5 per cent NaCl	7,030	235	7 710	1,015	10,770	1,040	10,070	970	8,170	695
		6,320	295	9 030	960	11,300	990	10,270	850	9,070	760
		6,610	290	11,220	990	8,130	1,020	10,870	910	5,340	785
		7,020	300	10,770	1,010	10,540	1,020	10,600	910		
			300								
	Average	6,745	284	9,675	994	10,185	1,017	10 452	910	7,527	747
2	Ideal neat, in 5 per cent $MgSO_4$	7,120	615	12 070	360	10,380	220	8,920	630	7,400	600
		7,810	640	12 530	500	11,420	330	8,070	655	8,440	650
		8,040	700	12,460	510	12,580	335	10,380	645	8,380	585
		8,550	740	9,400	560	10,860	270	12,750	675		
		8,175	630								
			710								
			615								
	Average	7,939	664	11 615	482	11,310	289	10,030	651	8,073	612
3	Ideal neat, in 1 per cent Na_2SO_4	8,420	510	10,670	335	9,200	890	10,040	690	9,000	725
		8,200	490	10 420	430	12,080	895	12,070	725	8,840	665
		8,800	445	11,880	365	11,570	655	8,220	725	9,300	705
		9,890	470	9,780	470	10,000	785	10 800	760		
			440								
			375								
			490								
			425								
	Average	8,827	455	10,687	400	10,712	806	10,282	725	9,047	698

APPENDIX—(Continued).

Lab. No.	CEMENT AND SOLUTION	Before immersion		After being in solution:							
				12 months		24 months		30 months		40 months	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
		7,380	495	6,540	605	7,900	685	7,380	740	6,220	580
		7,755	490	7,090	570	7,660	740	8,300	675	6,860	625
		9,435	540	8,970	730	7,900	650	5,720	825	6,490	690
4	Ideal neat, in 5 per cent Na_2SO_4	6,850	500	11,230	670	4,720	785	4,530	565		
		7,690	705								
		7,140	670								
			715								
	Average	7,708	588	8,457	644	7,045	716	6,482	701	6 523	632
		7,200	745	12.090	670	13,110	200	11,740	305	10,110	240
		7,190	690	12,230	545	8,820	290	11,000	160	10 050	115
		8,630	595	10,850	780	10,820	595	11,260	375	11 220	775
5	Ideal neat, in 10 per cent Na_2SO_4	7,825	735	11,140	645	13,640	550	11,060			
		8,760	710								
		8,100	650								
		8,510	690								
	Average	8,031	688	11,577	660	11 597	409	11,265	280	11,460	377
		12,160	695	9 420	620	4,280	415	6,000	715	6,210	460
		10,440	565	9 500	670	6 880	200	2,800	790	4,180	570
		9,290	705	8,500	705	6 450	205	3.010	460	4,760	335
6	Neat Ideal, 14 days in water, in 5 per cent Na_2SO_4	11,370	625	9,950	675	4,390	370	5,850			
			600								
			645								
			715								
			555								
	Average	10,815	638	9,342	669	5,500	297	4,415	655	5 050	455

APPENDIX—(Continued).

Lab. No.	CEMENT AND SOLUTION	Before immersion		After being in solution: 12 months		24 months		30 months		40 months	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
7	Neat Ideal, 14 days in water, in 5 per cent NaCl	8,160	410	9,300	1,055	8 030	860	8.310	370	No more specimens were available	
		9 820	540	8 720	890	9,310	895	9,250	975		
		8 870	610	8 020	885	12 080	870	8,750	765		
			405	8,350	790	11 760	760	5,800	940		
			575								
			580								
			555								
	Average	8 950	525	8,597	905	10,295	846	8,030	762		
8	Neat Ideal, 14 days in water, in 5 per cent Na_2CO_3	10,380	580	11 340	870	9,950	700	10,800	795	8,440	625
		9 410	745	9,250	880	10,460	730	9,760	630	12,090	705
		9,200	685	10,920	850	11,030	780	9.210	690	10,650	725
			665	11 130	720	9 870	660	9,860	765		
			480								
			925								
			695								
			630								
			550								
	Average	9,663	662	10 660	830	10,327	717	9,907	720	10,393	685
9	Neat Ideal, 14 days in water, in 5 per cent $NaHCO_3$	9,640	435	11,070	730	13,260	715	7,950	695	12,960	710
		8,000	435	7.710	980	3,600	760	13,040	700	14,760	740
		10,720	410	6,610	820	8,700	815	6.590	830	9,090	685
			470	11,380	860	9,970	710	11,420	690		
			445								
			345								
	Average	9,453	423	8 942	847	8,882	757	9,750	729	12,270	712

APPENDIX—(Continued).

Lab. No.	CEMENT AND SOLUTION	Before immersion		After being in solution:							
				12 months		24 months		30 months		40 months	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
10	Neat Ideal, 7 days in water, 3 months in air, in 1 per cent NaCl	4,380	1,080	6,200	565	9,060	845	8,820	660	9,190	600
		5,810	940	9,200	650	9,100	655	10,310	630	8,080	600
		6,700	790	9,360	690	10,850	730	9,280	640	6,580	580
		6,280	610	10,200	570	7,850	765	5,610	630		
		6,930	675								
		3,830	755								
		5,480									
		6,870									
	Average	5,791	774	8,740	619	9,215	749	8,505	640	7,950	593
11	Neat Ideal, 7 days in water, 30 months in air, in 5 per cent Na_2CO_3	10,920	655	11,480	790	No tests were made		12,510	715	11,720	615
		8,760	820	10,800	755			12 930	745	11,830	580
		8,880	650	12,030	650			9,670	615	8,350	455
		13,310	725	11,850	670			9,830	615		
	Average	10,467	712	11,540	701			11,235	672	10,633	550
12	Neat Ideal, 14 days in water, in 1 per cent NaCl	12,250	415	11 320	785	11,440	1,090	9,530	985	8,370	740
		12,390	425	11,570	600	10,790	810	12,000	840	12,340	750
		11,780	425	9,820	860	12,080	1,070	9,730	950	7,800	890
		11,110	425	6,980	670	11,250	820	9,610			
		10,970	495								
	Average	11,700	437	9,922	779	11,390	948	10,217	892	9,503	793
13	Neat Alkali-proof, 4 months in water, in 1 per cent NaCl+1 per cent Na_2CO_3+3 per cent Na_2SO_4	7,140	570	10 180	520	9,220	485	10,570	515	11,790	590
		8,920	635	8,220	720	10,860	490	10.140	575	8,580	500
		10,240	615	9,530	540	14,050	455	10,960	545	9,640	485
		9,320	565	11 380	520	11,470	540	10,630	545		
	Average	8,905	596	9,802	575	11,407	492	10,575	545	10,003	592

Appendix—(Continued).

Lab. No.	Cement and Solution	Before immersion		After being in solution:							
				12 months		24 months		30 months		40 months	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
14	Neat Ideal, 3 months in water, 1.25 per cent of each: NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$	6,070 10,110 5,600 6,580	490 430 475 420 460	11,060 9,110 10,770 10,480	950 810 955 950	9,040 9,460 6,510 5,710	370 870 860 1,075	8,680 7,910 9,120 6,630	840 755 725 910	7,070 8,840 6,750	800 890 890
	Average	7,090	455	10,355	916	7,680	794	8,085	807	7,553	860
15	Neat Ideal, in distilled water	7,800 5,040 9,360 8,740 8,190	625 535 440 400 470	5,420 5,980 5,080 12,100	705 740 680 740	6,850 9,360 12,540 9,490	730 785 770 695	11,650 9,700 12,630 9,650	635 585 700 790	10,470 10 560 8,600	645 680 710
	Average	7,826	494	7,145	716	9,560	745	10,907	677	9,877	678
16	Neat Ideal, 1.25 per cent of each: NaCl, Na_2SO_4, $MgCl_2$, $MgSO_4$	6,790 7,350 10,420 9,650	395 340 290 325	13,700 10,260 11,030 9,680	825 855 870 660	7,020 3,900 9,280 13,000	790 885 810 910	8,110 8,070 8,870 7,430	800 655 715 845	7,770 7,640 8,140	840 730 750
	Average	8,552	337	11,167	802	8,300	849	8,120	745	7,850	773
17	Neat Ideal, in solution of 1.33 per cent of each: $CaCl_2$, $MgCl_2$, and NaCl	6,850 5,010 4,820 6,150 5,450 6,060	350 450 380 420	8,600 6,860 6,000 7,890	350 350 335 310	7,570 10,770 9,120 7,980	910 775 845 845	6,720 8,390 6,470 10,260	745 795 860 790	8,400 9,250 8,460	680 730 605
	Average	5,723	400	7,837	336	8,860	844	7,960	797	8,703	672

APPENDIX—(Continued).

Lab. No.	CEMENT AND SOLUTION	Before immersion		After being in solution: 12 months		24 months		30 months		40 months	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
18	Neat Ideal, mixed with 1 per cent H_2SO_4. In 1 per cent of each: NaCl, Na_2CO_3, nad Na_2SO_4	9,340	490	9,670	550	9,970	785	9,940	745	12,940	750
		9,850	605	8,000	550	9,940	655	10 510	750	10,320	715
		9,020	795	7,350	520	9,000	710	10,940	700	8,640	780
		10,190	650	10,450	640	9,760	870	10,800	800		
		10,470	640								
	Average	9,774	636	8,867	565	9,667	755	10,547	749	10,633	748
19	Neat Ideal, mixed with 1 per cent ammonium sulphate. In solution containing 1.66 per cent of each: NaCl, Na_2CO_3, Na_2SO_4	8,010	410	8,400	700	11,940	750	9,050	1,025	8,980	650
		5,940	495	10,840	650	11,010	820	7,900	775	8,540	950
		5,610	525	10 540	665	12,380	895	7,980	965	10,010	920
		9,080	390	10,030	680	11,730	925	10,840	710		
		9,720									
		7,880									
	Average	7,706	455	9,952	674	11,765	847	8,942	869	9,510	840
20	1:3 Ideal, in solution containing 1.66 per cent of each: NaCl, Na_2CO_3, and Na_2SO_4	3,140	480	5,200	480	6,090	335	3,660	395	7,720	300
		3,770	360	6,400	365	6,570	415	6,760	385	5,890	280
		3,550	350	6,100	355	3,880	400	7,360	420	2,890	310
		3,050	475	6,390	425	3,410	430	3,980	390		
		3,940	370								
		5,070									
	Average	3,753	409	6,022	406	4,987	395	5,440	397	5,500	297
21	1:3 Ideal, in solution containing 1.25 per cent of each: NaCl, $MgCl_2$, Na_2SO_4, and $MgSO_4$	2,680	560	1,470	355	Could be crushed by hand					
		2,880	525	1,670	390						
		2,680	535	1,150	300						
		2,320	515	2,400	350						
		2,080	540								
	Average	2,528	535	1,672	349						

APPENDIX—(Continued).

Lab. No.	CEMENT AND SOLUTION	Before immersion		After being in solution:							
				12 months		24 months		30 months		40 months	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
22	1:1 Ideal, in solution containing 1.66 per cent of each: NaCl, Na_2SO_4, Na_2CO_3	7,710	780	8,700	835	10,440	835	9,740	885	11,610	870
		8,270	725	8 350	860	10,370	800	9,780	945	10,000	915
		9,530	745	7,850	850	9,180	800	9,320	780	9,760	930
		8,380	650	8,180	830	10 820	765	8,220	900		
		6,000	665								
		9,100									
	Average	8,165	693	8 270	844	10,202	800	9,265	877	10,457	905
23	1:1 Ideal, in solution containing 1.66 per cent of each: NaCl, $MgCl_2$, Na_2SO_4, $MgSO_4$	7,190	655	3,330	820	6,290	730	5,310	675	3,010	800
		8,210	630	8,200	885	6,490	405	5,190	740	3,800	670
		7,650	655	5,750	755	5,360	440	2,330	765	3,240	430
		5,900	600	7,360	805	2,770	710	5,240	630		
		6,640	765								
	Average	7,118	661	6,160	816	5,278	571	4,517	702	3,350	633
24	1:1 Ideal, mixed with 5 per cent sulphuric acid. In solution containing 3 per cent of each: NaCl, Na_2CO_3, and Na_2SO_4	4,880	610	7,630	500	9,640	905	8,110	850	8,530	950
		7,570	700	7,690	595	8,310	705	9,270	910	9,430	945
		7,090	610	6,500	530	9,950	900	8,000	810	9,280	1,000
		7 340	610	7,500	410	9,160	940	8,880	900		
		6 880	780								
	Average	6,752	662	7 330	509	9,265	862	8,565	867	9,080	965
26	1:2 Ideal, in solution containing 3 per cent of each: NaCl, Na_2CO_2, and Na_2SO_4	4,960	555	6,000	161	5,340	470	4,010	555	2,230	150
		3,640	530	6,160	455	6,080	630	3,480	500	6,060	380
		3,150	550	5,020	480	6,320	405	7,010	575	5,200	110
		5,150	575	6,760	425	6,140	500	4,150	250		
		4,360	575								
	Average	4,252	557	5,985	453	5,970	501	4,662	470	4,497	213

APPENDIX—(Continued).

Lab. No.	CEMENT AND SOLUTION	Before immersion		After being in solution: 12 months		24 months		30 months		40 months	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
27	1:3 Ideal, in solution containing 3 per cent of each: NaCl, Na_2CO_3, and Na_2SO_4	3,350 2,640 1,720 1,810 2,560	475 435 465 440	2,780 2,170 2,540 2,525	450 515 535 575	3,230 2 300 2,800 2 900	600 570 575 600	3,370 2,480 2,680 2,400	575 470 465 575	3,220 3,000 3,890	590 520 540
	Average	2,404	456	2,504	519	2,807	586	2,732	521	3,370	550
28	1:1 Ideal, mixed with solution containing 1 per cent Na_2HPO_4 and 1 per cent sulphuric acid. Kept in solution No. 13	4,780 7,320 6,010 5,760	530 725 700 670	8 010 8,350 7,060 7,400	750 810 830 850	6,730 8,600 8,480 7,300	800 800 775 855	7,730 8,600 8,760 8,890	780 810 780 745	7,530 9,190 9,030	930 940 810
	Average	5,967	656	7,705	815	7,777	807	8,495	779	8,583	893
29	1:1 Ideal, mixed with 1 per cent sulphuric acid. Kept in solution No. 13	5,310 8,910 8,470 7,230 6,680	675 675 785 645	7,600 8 630 7,450 6,850	755 710 715 720	8,980 8 330 8,580 9,200	850 790 835 750	9,980 6,160 10,410 8,190	750 880 860 825	8,670 5,090 9,260	780 880 820
	Average	7,320	695	7,632	725	8,772	806	8,685	829	7,673	827

APPENDIX—(Continued).

Lab. No.	CEMENT AND SOLUTION	Before immersion		After being in solution: 1 week		2 weeks		3 weeks		4 weeks	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
30	Neat Ideal, Solution No. 10, 7 days in distilled water before immersion in solution	3,180	240	7,030	685	6,470	880	4,960	730	6 740	745
		6,360	265	6,060	685	5 100	710	6,270	925	5,970	980
		7,940	200	5,950	883	7,100	870	6,060	850	7,240	1,050
		6,480	310					3,600		6,680	
		6,760									
	Average	6,144	254	6,550	750	6,233	820	5,222	833	6,657	925

Lab. No.	CEMENT AND SOLUTION	After being in solution: 5 weeks		6 weeks		30 months	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
30	Continued	7,590	850	7,240	1,070	7,310	700
		3,970	950	6,220	735	7,730	725
		5,820	930	5,440	735	4,790	720
		5,720				6,490	690
		6,680				6,460	
	Average	5,956	910	6,300	847	5,656	709

APPENDIX—(Continued).

Lab. No.	CEMENT AND SOLUTION	48 hours in damp oven		After being in solution:							
				1 week		2 weeks		3 weeks		5 weeks	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
31	Neat Ideal, Solution No. 10	5,700	280	4,800	845	5,580	950	6,130	1,060	5,990	970
		4,330	250	4,400	775	3,570	980	8,180	970	7,280	970
		4,080	255	7,320	755	4,290	965	5,270	995	6,180	1,060
		4,170	210					8,510		5,890	
	Average	4,570	249	5,507	795	4,460	965	7,022	1,008	6,277	1,000
		After being in solution:									
		6 weeks		8 weeks		17 weeks		20 weeks		36 weeks	
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
31	Continued	7,430	1,145	7,970	1,110	6,050	1,106	8,430	1,140	5,420	950
		6,430	1,090	6,610	1,020	8,390	995	7,110	965	7,300	1,315
		6,930	1,000	6,350	990	7,850		7,610	1,165	7,560	1,120
		6,140		7,130		6,300		5,770		8,010	1,320
						7,860		5,320			
								7,180			
								5,970			
	Average	6,732	1,078	7,015	1,040	7,236	1,047	6,770	1,090	7,072	1,176
				After being in solution:							
				21 months		25 months		30 months		40 months	
				lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
31	Continued			9,200	1,035	8,840		8,670	1,085	7,840	615
				8,320	1,000	9,110		6,860	1,000	6,310	830
				9,300	1,185	9,680		7,090	1,020	6,820	810
				8,900	1,035	5,700		6,040			
	Average			9,180	1,064	8,332		7,165	1,035	6,900	752

Appendix—(Continued).

Lab. No.	CEMENT AND SOLUTION	Before immersion		After being in solution: 12 months		24 months		30 months		40 months	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
33	Neat Ideal, 48 hours in damp oven, Solution No. 10	lbs. 3,830 4,240	lbs. 315 365	lbs. 12,910 11,000 9,010 8,890	lbs. 320 275 265 330	lbs. 10,160 10,320 9,360 9,680	lbs. 1,020 1,120 1,160 1,120	lbs. 7,840 6,590 6,910 7,600	lbs. 980 1,275 1,240 1,030	lbs. 8,450 8,510 6,800	lbs. 1,140 1,200 1,185
	Average	4,035	340	10,440	297	9,880	1,105	7,325	1,131	7,920	1,175
36	1:2 Ideal, Solution No. 13	4,050 2,200 2,570 5,130	320 320 265 275 325	6 010 4 010 3,500 3,740	420 320 330 410	4,370 4,230 5,880 8 450	460 440 350 465	7,950 3,000 3,520 2,580	535 560 415 525	4,690 3,865 4,180	480 425 535
	Average	3,487	301	4 315	370	5,732	429	4,262	509	4,244	480
37	Neat Ideal, in water, titrated daily with sulphuric acid to a slightly acid reaction. Water changed weekly	4,860 6,470 4,260 5,770 5,080	365 325 425 265 250	9,220 10,770 10,390 8,110	760 700 865 725	8,850 10,740 11,000 11,070	670 735 585 680	12,020 9,770 11,070 9,740	615 700 565 835	11,790 9,000 11,130	230 265 270
	Average	5,288	326	9,622	726	10,165	667	10,650	679	10,640	255
38	Neat Ideal, 5 per cent sodium hydroxide solution	6,380 5 670 6,810 4,350	600 630 645 500	8,030 9,790 8,000 8,920	950 820 1 010 840	11,870 10,600 9,270 8,120	870 930 950 930	8,670 6,800 10,590 8,000	990 910 965 1,015	6,560 9,070 6,520	625 940 740
	Average	5,802	594	8,685	905	9,965	920	8,515	920	7,383	768

APPENDIX—(Continued).

Lab. No.	CEMENT AND SOLUTION	Before immersion		After being in solution:							
				12 months		24 months		30 months		40 months	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
39	Neat Ideal, in distilled water, titrated daily with H_2SO_4 to slightly acid reaction. Water changed after every test for strength	4,540	330	10,010	420	10,180	730	11,680	775	11,010	735
		5,520	360	11,050	510	9,760	870	12,750	900	9,790	855
		5,220	415	10,050	540	10,380	845	11,690	800	11,030	825
		4,320	420	9,850	430	11,950	900	12,280	810		
		4,200	360								
	Average	4,760	387	10,240	475	10,567	836	12,100	821	10,607	805
40	1:1 Iron ore cement, Solution No. 13	2,590	420	10,310	900	10,400	950	11,300	1,040	10,640	860
		2,770	385	5,000	870	11,130	1,015	9,230	1,000	10,390	870
		2,160	365	7,000	880	11,070	920	10,080	1,000	12,140	985
		3,140	480	8,900	785	9,100	950	10,380	915		
		5,620	480								
	Average	3,256	426	7,802	859	10,425	959	10,247	989	11,057	905
43	Neat Ideal, Solution No. 14, titrated with H_2SO_4 once a week to acid reaction	8,350	320	12,430	655	10,730	845	11,110	1,015	10,880	1,000
		6,880	175	14,030	660	10,800	885	12,210	505	8,160	930
		6,760	240	11,160	470	13,670	1,010	10,390	795	11,020	1,010
		6,780	225	12,410	540	10,120	760	9,600	565		
		7,040	295								
			250								
			320								
	Average	7,162	261	12,570	581	11,330	876	10,827	720	10,020	980
44	1:1 Apple cement, Solution No. 13	4,600	525	9,470	715	9,950	885	10,140	790	9,280	770
		3,390	500	8,880	750	10,600	855	10,670	790	10,710	710
		4,790	480	8,440	870	7,590	745	9,300	760	10,120	740
		3,850	380	9,010	915	9,340	950	10,440	860		
	Average	4,157	471	8,950	812	9,370	859	10,137	800	10,037	740

Appendix—(Continued).

Lab. No.	CEMENT AND SOLUTION	Before immersion		After being in solution:							
				12 months		24 months		30 months		40 months	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
45	Neat Ideal, Solution No. 4, titrated to neutral once a week with sulphuric acid	6,280	360	10 460	805	10,400	710	11,060	835	9,350	840
		7,190	310	11 360	990	9,520	950	8,000	880	8,610	640
		5,520	240	9,920	1 000	10,790	770	8,320	915	11,020	740
		5,720	225	10 390	815	8 830	785	9,770	801		
		6 960	245								
	Average	6,174	276	10,522	902	9,885	804	9,287	860	9,660	740
46	1:1 Ideal, in distilled water	5,970	450	9 440	605	7,420	765	12,700	725	8,880	690
		7,550	455	9,590	575	9,000	775	9,280	760	9,060	735
		7,100	420	9,830	565	8 310	740	10,690	780	8,620	795
		5,210	410	11 090	540	9,160	785	8,260	760		
	Average	6,457	434	9,987	571	8,472	766	10,232	756	8,853	740
49	1:1 Ideal, 30 days in water, Solution No. 13	3,160	615	9,970	815	7 020	900	8,960	860	10,530	825
		5,010	535	8,850	890	10 040	935	9,540	810	6,570	835
		4,270	580	7,850	880	9 400	830	8,860	990	9,820	870
		4,350	585	8,370	860	7,320	1,000	10,560	870		
		5,380	625								
		4,860									
	Average	4,505	588	8,760	861	8,445	916	9,480	882	8,973	843
50	1:1 Iron ore cement, 30 days in water, Solution No. 13	4,400	540	8,390	885	8,740	935	9 240	935	9,390	970
		4,130	505	9,370	920	9,750	1,035	12,480	920	8 900	1,080
		3 200	560	9 720	875	10,650	850	10 440	1,010	9,870	935
		3,880	470	9,210	815	10,670	900	10,710	880		
		3 780	535								
		4,800									
	Average	4,032	522	9,172	874	9,952	930	10,717	936	9,387	995

APPENDIX—(Continued).

Lab. No.	CEMENT AND SOLUTION	Before immersion		After being in solution:							
				12 months		24 months		30 months		40 months	
		Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n	Comp.	Tens'n
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
51	1:1 Alkali-proof cement, 30 days in water, Solution No. 13	3,040	560	6,260	785	6,710	860	6,120	920	7,490	770
		4,440	560	5,450	730	9,690	910	7,320	775	7,650	820
		5,270	525	5,760	840	8,630	900	6,970	840	6,600	690
		3,470	565	6,350	710	6,710	830	8,090	875		
		5,080									
		3,270									
	Average	4,095	552	5,955	766	7,935	875	7,125	852	7,247	760
54	1:1 Ideal, for mixing 1 per cent sulphuric acid used; after that, 7 days in water; Solution No. 13	4,120	475	9,490	880	10 280	940	9,690	810	8,490	1,040
		4,100	500	10,240	800	8,540	980	8,740	910	9,050	880
		3,920	480	8,480	930	10,280	1,010	11,910	855	11,610	810
		3,000	530	9,240	885	9,790	940	10,290	915		
			555								
	Average	3,476	488	9,362	874	9,722	967	10,157	872	9,717	910
60	Neat Alkali-proof cement, Solution No. 2	3,365	335	7,730	1,090	8,980	1,005	8,770	985		
		3,480	365	8,720	950	8,910	985	6,840	900		
		2,830	380	7,720	955	11,520	1,035	8,260	990		
		4,050	340	8,100	990	11,360	1,060	10,130	850		
		3,550	340								
	Average	3,735	352	8,038	996	10,192	1,021	8,350	931		

Twenty-Sixth Annual Report

of the

University of Wyoming

Agricultural Experiment Station

1915-1916

LARAMIE, WYOMING
U. S. A.

UNIVERSITY OF WYOMING
Agricultural Experiment Station
LARAMIE

*Absent on leave, 1915-16.
†Appointment for 1915-16 only.

AGRICULTURAL EXPERIMENT STATION,
UNIVERSITY OF WYOMING.

To the Board of Trustees,
The University of Wyoming.

SIRS:—In accordance with the act of Congress approved March 2, 1887, establishing and regulating agricultural experiment stations, and the act of Congress approved March 16, 1906, known as the "Adams Act", I have the honor to submit herewith the Twenty-sixth Annual Report of the Agricultural Experiment Station of the University of Wyoming, for the fiscal year ending June 30, 1916.

Respectfully submitted,
C. A. DUNIWAY,
Acting Director.

UNIVERSITY OF WYOMING,
LARAMIE, WYOMING,
August 31, 1916.

THE UNIVERSITY OF WYOMING,
OFFICE OF THE BOARD OF TRUSTEES,
LARAMIE.

To His Excellency,
Governor John B. Kendrick,
Cheyenne, Wyoming.

SIR:—In accordance with Chapter 51, Section 1, of the Session Laws of 1899, as President of the Board of Trustees of the University of Wyoming, I hereby submit to you that portion of the report of the Board of Trustees which refers to the Annual Report of the Director of the Agricultural Experiment Station and other members of the Station Council, for the fiscal year ending June 30, 1916.

Respectfully submitted,
TIMOTHY F. BURKE,
President of the Board of Trustees.

LARAMIE, WYOMING,
August 31, 1916.

Report of Acting Director

The granting of a sabbatical leave of absence to Director H. G. Knight for the academic year 1915-16 led to the designation of the President of the University as Acting Director. It is in this capacity that a brief formal report is submitted by the undersigned in accordance with law.

Under the circumstances there has been no effort during the year to inaugurate new policies or to initiate new lines of investigation. The several departments have continued researches on plans heretofore adopted, but with greater effectiveness than during the preceding year because of full use of improved facilities in the new laboratories of Agricultural Hall.

The reports which follow give in summary form the results which have been obtained. Reference to these statements will give a sufficient indication of the progressive conditions characteristic of the Station.

ORGANIZATION AND STAFF.

The Agricultural Experiment Station of the University of Wyoming is organized as follows, with the staff who have served during the past year:

Administration.—Acting Director, C. A. Duniway; Secretary, F. S. Burrage; Clerk, C. D. Moir.
Agronomy.—T. S. Parsons and P. T. Meyers.
Animal Husbandry.—A. D. Faville.
Botany and Horticulture.—Aven Nelson.
Chemistry—S. K. Loy, F. E. Hepner, O. A. Beath.
Engineering Chemistry.—Karl T. Steik.
Irrigation Engineering—J. C. Fitterer.
Parasitology.—J. W. Scott.
Veterinary.—J. I. Kirkpatrick.
Wool.—J. A. Hill.

PUBLICATIONS.

Owing to limitation of funds, the Station has issued only those publications required for its operation. *The Wyoming Farm Bulletin* has been made the organ of the Extension Division of the Agricultural College, but members of the Station contribute to it appropriate popular articles.

ANNUAL REPORT.

Early in the year the Twenty-fifth Annual Report of the Director was compiled and published. Besides the usual general review and the departmental summaries, it contained special articles by John W. Scott on "A Progress Report on Sarcocystis Tenella", by A. D. Faville on "Branding Paints", and by O. L. Prien on "Tuberculosis and Its Rapid Transmission".

BULLETINS.

The following Bulletins have been issued and distributed during the year:

Bulletin No. 106, on

I. Cottonseed Cake vs. Cold Pressed Cottonseed Cake for Beef Cows.

II. Mixed Grains vs. Cottonseed Cake for Growing Beef Cattle.

CONCLUSIONS.

In rations for beef cows two and four-tenths pounds of cottonseed cake when fed with native hay proved practically equal in feeding value to three pounds of cold-pressed cake.

In growing rations for beef heifers a ration of four pounds of a mixture of equal parts of corn meal and mill run bran gave better gains than did two pounds of cottonseed cake.

Under certain conditions the ration in which the grain mixture was used made the cheaper gains; under other conditions the cottonseed ration was more economical.

Bulletin No. 107, on "Swine Feeding":

I. (a) Pea Pasture for Fattening Pigs.
(b) Hurdling Pea Pasture for Pigs.

II. (a) Alfalfa Tea for Growing Pigs.
(b) Corn Meal vs. Barley Meal for Fattening Pigs.

III. (a) Pea Hay vs. Alfalfa Hay for Brood Sows.
(b) Alfalfa Meal in Fattening Rations for Sows.

CONCLUSIONS.

Pea pasture gave good returns in fattening rations.

Hurdling pea pasture effected a large saving of peas.

Pigs that had been on pasture previously made better gains when put on dry feed than did pigs that had no pasture.

Returns from an acre of pea pasture were good.

Cross-bred and pure-bred pigs made practically the same gains.

Alfalfa tea added to a ration increased gains, though it did not appear to be of much value.

Barley meal proved equal to corn meal for young fattening pigs.

Alfalfa hay gave better returns in maintenance rations for brood sows than did pea hay.

A mixture consisting of four parts corn meal and one part alfalfa meal proved less satisfactory as a fattening ration for brood sows than did corn meal alone.

Bulletin No. 108, on "Cattle Feeding":

I. Oat and Pea Silage in Maintenance Rations for Steers.

II. Oat and Pea Silage for Beef Cows.

III. Oat and Pea Silage for Growing Cattle.

DIGEST.

In rations for steers oat and pea silage, when fed with native hay, produced much heavier and cheaper gains than did native hay alone.

Twenty-eight pounds of silage was much more valuable than ten pounds of native hay in steer rations.

Oat and pea silage used with alfalfa hay made a very satisfactory ration for breeding cows of the beef breeds.

Silage added to a ration of grain and alfalfa for growing beef stock gave cheaper gains than did a grain and alfalfa ration.

Silage gave remarkably good returns when fed with alfalfa in rations for young cattle.

Bulletin No. 109, on "Sheep Feeding":

I. (a) Oat and Pea Silage for Fattening Lambs.
(b) Corn vs. Barley for Fattening Lambs.

II. Oat and Pea Silage for Breeding Ewes.

III. Oat and Pea Silage for Ram Lambs.

DIGEST.

The heaviest gains made by fattening lambs were on a ration of corn and alfalfa.

Valuing alfalfa at $12.00 and silage at $4.00 per ton, a ration in which silage was used made as cheap gains in fattening lambs as did the corn and alfalfa ration.

Alfalfa and silage without grain did not prove to be a satisfactory fattening ration for lambs.

When barley replaced corn in a fattening ration gains were somewhat lower.

Oat and pea silage may be used satisfactorily in rations for breeding ewes.

In growing rations for ram lambs oats and pea silage may be used to replace part of the alfalfa.

GENERAL ACTIVITIES.

The Station exists primarily for research, for the discovery of scientific truths of value to any form of agricultural industry. Its staff, laboratories, equipment, library, farms, herds, and flocks are maintained for these purposes. Its work, however, is closely associated with the conditions under which agricultural industries are actually conducted in Wyoming. The members of the Staff give their services in generous measure to stockmen, ranchers and farmers for the solution of their practical problems. Hundreds of inquiries are answered by correspondence every month. Bulletins are distributed widely to all who wish them. Institutes and Short Courses receive all the aid and time that due regard for research permits. Kept within proper limits, these activities help investigators by relating their work to realities. In Wyoming even the rapid growth of the Extension Division of the College has not kept pace with the demands which press upon the institution for field instruction and demonstration. The results of scientific experimentation are no longer slighted, but are being welcomed and even eagerly sought.

STATION NEEDS.

This topic can be only imperfectly discussed, being restricted to suggestions capable of immediate realization, and not extended to far-reaching plans for the perfection of Station service.

Certain laboratories in Agricultural Hall have not yet been equipped. It is expected that appropriations will be available during the coming year to make most of these improvements.

Substantial additions to breeding herds and flocks on the Stock Farm are urgently needed. If possible, several thousand dollars should be appropriated at once for purchases, chiefly of sires. At the same time, new sheds and improved feed yards ought to be provided.

Agronomy experiments require a substantial greenhouse, the cost of which ought to be covered in next year's budget.

Several sub-stations for combined experimental and demonstration work, both in Agronomy and Animal Husbandry, ought to be provided in different sections of the state. Federal regulations forbid the use of Hatch and Adams Funds for sub-stations, so that the new work would have to be supported by state funds. The several farms now maintained under the direction of the State Farm Board could be admirably adapted for these purposes if they were administered through the Agricultural College, the Extension Division and the Experiment Station. The value of the scientific work at the main Station would be increased many times if the use of sub-stations under a single management facilitated comparative experiments on a large scale and furnished the means for practical demonstrations.

In some departments of the Station, more particularly in Parasitology and Wool, more highly trained assistants are needed than can now be found among our College students. During the coming year, it is hoped that such assistants may be employed.

As always, and in common with all departments of the University, the Station faces the problem of advancing salaries on some reasonable basis. The subject needs considerate attention and action as prompt as possible.

C. A. Duniway,
Acting Director.

Financial Statement of the Treasurer

UNIVERSITY OF WYOMING

AGRICULTURAL EXPERIMENT STATION

IN ACCOUNT WITH

THE UNITED STATES APPROPRIATION, 1915-1916

DR.

To receipts from the Treasurer of the United States, as per appropriations for fiscal year ended June 30th, 1916, under acts of Congress approved March 2nd, 1887, and March 16th, 1906:

Hatch Fund	$15,000.00
Adams Fund	15,000.00

CR.

	Hatch	Adams	
By Salaries	$ 7,770.15	$ 9,297.64	
Labor	2,752.13	662.75	
Publications	1,220.94	....	
Postage and Stationery	58.07	....	
Freight and Express	21.70	91.00	
Heat, Light, Water and Power	257.05	51.24	
Chemicals and Laboratory Supplies	69.14	847.16	
Seeds, Plants and Sundry Supplies	271.25	46.51	
Fertilizers	100.00	....	
Feeding Stuffs	1,578.80	1,232.51	
Library	22.92	81.27	
Tools, Machinery and Appliances	319.31	161.38	
Furniture and Fixtures	32.50	....	
Scientific Apparatus and Specimens	126.04	1,343.23	
Livestock	400.00	316.00	
Traveling Expenses	....	117.31	
Buildings and Land	....	752.00	
Contingent Expenses	....	....	
	$15,000.00	$15,000.00	$30,000.00

We, the undersigned, do hereby certify that we have examined the books and accounts of the University of Wyoming Agricultural Experiment Station for the fiscal year ending June 30, 1916; that we have found the same well kept and classified as above, and that the receipts for the year from the Treasurer of the United States are shown to have been $30,000 and the disbursements in the Hatch Fund $15,000, and in the

Adams Fund $15,000, for all of which proper vouchers are on file and have been by us examined and found correct.

And we further certify that the expenditures have been solely for the purpose set forth in the act of Congress approved March 2, 1887, and the act of Congress approved March 16, 1906. (Signed) A. B. Hamilton,
W. S. Ingham.

Attest:

Frank Sumner Burrage,
Custodian of Seal.

(seal)

Report of the Agronomist

BY T. S. PARSONS.

Weather conditions for the season of 1915 were on the whole rather unfavorable to crops in this locality. There was a considerable growth of forage, but owing to cold, wet season, grains were slow in maturing and the yields were much lighter than in 1914. The second crop of alfalfa came on well and grasses made good growth. Weather observations for the months of July, August, and September show peculiar conditions. The month of July, when the most rapid growth of crops is expected to begin at this altitude, was unusually cold and wet. Frequent hail storms occurred in the vicinity, doing considerable damage, but the Agronomy Farm fortunately escaped these storms. August continued cold and wet, preventing the maturing of grains. The same conditions maintained through most of the month of September. On account of the excessive rainfall, several acres of oat ground became so soft that it was impossible to cut the grain. The weather conditions through October and November became more nearly normal, so that it was possible to finish up the threshing and other fall work in good shape. The ground was in good shape for plowing and most of the farm was fall plowed.

WEATHER CONDITIONS 1916.

The winter of 1915-1916 was about an average one. There was not a great deal of snow, but considerable cold weather. There was no winter killing of alfalfa or fall grains. Spring work began about March 25. The season up to July 1st was very unfavorable for crop growth, being dry and cold, quite severe frosts prevailing up to the latter part of June. A peculiar thing was noticeable, however, while frosts were frequent

and at times quite severe, but little harm was done to the crops directly by the frosts, their effect being much less severe on account of the dry season. The effect of the cold weather seemed to be to hold the grain crops back, causing them to head out very short. The grain crops showed very little growth up to July 1.

While the first crop of alfalfa was severely injured by frosts in 1915, an abnormally wet season, there was very little or no effect of the frost in the first crop this year on account of the dry weather.

ALFALFA.

About one-half of the alfalfa seeding in 1915 came out well and produced a good crop this year. The balance was in low grounds and on account of the wet season killed out. The seeding was done with a broadcast seeder and with a drill, with a nurse crop and without. There seems to be no difference in the stands obtained by the different methods of seeding or whether a nurse crop was used or not. The main factors of success seem to be in the selection of good seed and the proper preparation of the soil. About the middle of May seems to be a good time to sow alfalfa. Six acres of new alfalfa were sown in May, 1916. This is an excellent stand at this date (June 30). Two hundred and fifty acres were sown this year on land near the Agronomy Farm, as were several smaller areas in the Laramie Valley under the direction of the Agronomist. All appear to be successful.

Some of the older variety plots of alfalfa had been badly killed out, so they were plowed up and prepared for reseeding. The Baltic, Liscomb, and some other varieties will be tried. The Grimm variety still remains the best of all the varieties grown at the Station. Special attention is being given to the production of alfalfa seed this year. A bulletin embodying the results of five years' work with alfalfa has been prepared and is now ready for the press.

SMALL GRAINS.

The small grain projects, early and late seeding and rate of seeding were held in abeyance this year in order to clean up the plots. These plots on which grains have been grown for five or six years in succession had become very foul, containing a great many weeds and much volunteer grain. They were, therefore, plowed in the fall of 1915 and disked and harrowed at intervals through the season of 1916, and will be plowed again this fall.

One year's experiments seem to indicate that there is nothing gained by seeding too early. By seeding later there is more time to clean the land of volunteer stuff and weeds by cultivation, while germination and growth start more quickly in the later sowing. Where there was a month interval between times of sowing there was only a week's difference in the time of harvest. These projects will be taken up again in the spring of 1917. A bulletin on small grains embodying five years' experiments is now in process of preparation.

POTATOES.

The potato project was continued in 1916, as the unfavorable season of 1915 gave but poor results as to yields. No blight appeared in the vines in 1915, but the cold, wet season did not permit a healthy growth of vines and yields were light. The latter half of May seems to be the proper time for planting at this altitude. The Red McClure variety was selected for this year's work and promises better yields at this date (June 30) than any variety grown at the Station the past seven years.

FORAGE CROPS.

The forage crops, such as peas and oats and barley and oats, were grown for ensilage. No special experiments are being conducted along this line at present except as to the use of these crops in the rotation project.

The pasture and meadow grass project has been completed and a bulletin on the subject is being prepared. The sweet

clover project was completed in the fall of 1915 and a bulletin is now ready for publication.

FERTILIZERS.

The commercial fertilizer project has been completed and results can be published as soon as soil analyses are made.

The usual application of five tons per acre of barnyard manure was made during the winter. While this manure has greatly increased the fertility of the soil and improved its physical texture, it has, at the same time, brought in a large amount of weed seed. It is thought best at the present time to omit the application of manure for one or two years, in order that the weeds may be brought under control.

CROP ROTATIONS.

The crop rotation project was continued this year. This is the second year's work. No results can yet be determined, as the work must be continued for a period of at least five years.

IMPROVEMENTS.

The sum of $300 was allowed for repairs and improvements at the Agronomy Farm in 1915-1916. This was used in the building of a forge for blacksmith work, the purchase of tools, the building of a concrete runway through the machinery barn, the digging of a well, fencing, and other repairs. About fifty trees were set out this year to replace those which were killed out last year. There is now a good well of drinking water with a pump at the house. As soon as funds are available the well will be cased up with tile and a pump and sink placed in the kitchen.

The fence on the west side of the farm has been placed over on the surveyed line. This gives several acres of new land that can be broken up.

A team of mares was purchased last July for use on the farm.

NEW MACHINERY.

New machinery has been added to the farm equipment as the old was worn out. During the year a sulky plow, a hay press, a hay rake, and a grain binder have been purchased. The press enables a great saving to be made in the threshed straw, as this baled straw finds ready sale in the market.

SEED DISTRIBUTION.

But few seeds were distributed to farmers in the spring of 1916, as the Agronomist desired to get complete returns as possible from the 1915 distribution. Of the 41 persons who received oats, wheat, and barley for trial in 1915, a large majority reported. In most instances they were well pleased with the grains sent and many reported that they had sufficient seed to plant their entire acreage this year. The table is for those reporting on the distribution:

GRAIN DISTRIBUTION BY COUNTIES.

COUNTY	Wheat No. Coop.	Oats No. Coop.	Barley No. Coop.
Albany	5	5	4
Big Horn	....	1	....
Carbon	1	1	1
Crook	1	1	....
Fremont	9	8	8
Goshen	1	1	3
Laramie	1	....	1
Lincoln	1	....	1
Natrona	2	2	2
Niobrara	1	1	1
Park	1	1	1
Sheridan	....	....	1
Sweetwater	....	4	2
Washakie	1	1	....

As will be seen by the table, the grains were well distributed over the state and should be the means of placing a large amount of good grain in the hands of the farmers. One farmer wrote that he would have several hundred bushels this year from his 1915 distribution.

This year the work of distributing winter wheat was taken up in a small way. In 1915 three hundred pounds of Buffum's No. 17 winter wheat was sent to the manager of the Rock River projects. This promises better than any other winter wheat grown there this year. Seven lots of this winter wheat have been sent out to farmers in Albany County and nine lots to farmers in other parts of the state. Each lot sent is sufficient to plant one acre.

The Superintendent of State Dry Farms reported that oats received from this Station yielded better than any other variety at the Jireh Farm. This distribution work should be extended as far as funds will permit.

COOPERATION.

In the spring of 1916 the Agronomy Department undertook some cooperation work with the Department of Agriculture in the testing of various grains. Five varieties of oats, five varieties of barley, and two varieties of wheat were sent for trial. These were planted and some of them bid fair to produce well under local conditions.

WINTER GRAINS.

Wyoming is short on winter grains. Winter wheat does well in all parts of the state, but no other winter grains have been extensively grown with the exception of winter emmer, and this has only been grown in limited areas of the state. More winter grains should be grown and the Agronomy Department has been working to find those hardy enough for this purpose. At the altitude of the Experiment Station no winter grains except wheat have survived the winters until this year. Last year winter emmer, winter speltz, and winter wheat were sown in July. These all came through the winter in good shape. The emmer and speltz are very promising crops, and by sowing them early, so that they can become well established before freezing, they will undoubtedly stand the winters in all parts of the state. This year experiments in the early sowing of winter oats, barley, and speltz are being tried out.

Late in the fall of 1915 the Agronomist received a small quantity of winter speltz from County Agent W. R. Reeves of Crook County. A row of this was sown in the garden. It was so late in the season, however, that the seed did not germinate. It came on well this spring, however, and promises to be a good winter grain. Mr. Reeves reports heavy yields on the dry farms in his county. A larger area will be sown at the Station this fall.

Mr. B. S. Tedmon, County Agent of Platte County, reports good yields of white winter barley this year.

SEED ANALYSES.

As State Seed Analyst the Agronomist the past year tested 601 samples of seed for the Dairy, Food and Oil Department and reported purity and germination on the same. A sixty-four page bulletin was also prepared, giving the results of the tests and other information. A number of tests were also made for farmers and other individuals who sent seeds direct to the laboratory, and an annual report was made to the Dairy, Food and Oil Commissioner in September. Farmers and others should avail themselves of the advantages of the seed laboratory more freely than they do. Considerable apparatus for aiding in the analysis of seeds was added to the laboratory equipment this year, which greatly facilitates the work.

EXTENSION WORK.

The Agronomist has been called upon to do more extension work the past year than any year before. But as there was help provided in the department to care for the teaching work, the outside work was more easily done. During the year the Agronomist devoted nine weeks to farmers' institutes, two weeks to teachers' institutes, three weeks to county and state fairs, and one week to a demonstration train, making a total of fifteen weeks.

OTHER WORK OF THE AGRONOMIST.

In addition to the regular duties of the office, the Agronomist has furnished material for the Agricultural College Department of the *Wyoming Stockman-Farmer,* written various articles for the *Wyoming Farm Bulletin,* prepared a bulletin on sweet clover and one on alfalfa, and has four other bulletins under way. He has also written many articles on Wyoming conditions for farm and other newspapers and has written many special articles as requested. Many farms in the vicinity of Laramie have been visited and advice given as to management, kinds of seed to use, etc.

The correspondence work of the office is constantly increasing. Many inquiries concerning farm topics and many plants and seeds are sent for identification. All of these inquiries, with the assistance of Dr. Nelson and other members of the Station Staff, are answered as promptly as possible. The Agronomist has answered on an average nearly 300 letters per month the past year. The clerical work of the office has increased to such an extent that a stenographer can be employed to good advantage about four hours per day.

FARM LABOR.

The Agronomist has had direct management of the farm the past year. A foreman and one other regular assistant have been employed throughout the year. During the summer vacation of 1915 three students were employed. Two were employed during the vacation of 1916. Owing to the multiplicity of other duties the Agronomist is unable to give the attention to the details of taking notes, etc., that should be given. It is suggested that this work be given to a student assistant next year. The Assistant in Agronomy will be able to devote some time to research work the coming year. His time will be largely taken up with teaching, however, therefore the research work will be confined mostly to that which can be done in the laboratory, and but little of his time can be devoted to work at the farm.

RECOMMENDATIONS.

The Agronomist has but few recommendations to make at this time, as things are in very good shape in the department. Another horse will be purchased with funds provided this year. Still another horse is necessary, however, as a three and a two-horse team can often be used to good advantage. The farm buildings will all need painting within the next year, and another house should be built. The small greenhouse which is now available will be a great help. A good sized greenhouse should be provided as soon as possible.

CONCLUSION.

More than six years' work at the Experiment Station show that the agricultural possibilities of Wyoming are great. The relations of this department with the other departments of the Station have been altogether pleasant.

Report of the Animal Husbandman

BY A. D. FAVILLE.

EXPERIMENTAL WORK.

The cattle and sheep feeding work undertaken during the past year was planned with the idea of still further testing the value of oat and pea silage in maintenance, growing, and fattening rations. Experimental lots of steers, beef breeding stock, ewes and lambs were fed silage rations formulated to meet the needs of western stockmen. Results as yet unpublished check in general with data appearing in Bulletins Nos. 108 and 109, and show that the silo has a definite place in western agriculture.

Rye, barley, and barley and meat meal were tested in rations for fattening swine. Gains made by all the lots were good, barley and meat meal giving the most rapid gains and rye showing the best returns per hundred pounds of feed consumed.

IMPROVEMENTS AND EQUIPMENT.

No new buildings have been erected at the farm and improvements made have been of a minor nature.

Additional trees have been planted and a large number that died during the winter have been replaced.

Comparatively few additions have been made in the stock department, due to lack of funds. Purchases were distributed as follows: 1 Ayrshire bull, 3 Ayrshire heifers, 2 long-wooled rams, 4 medium-wooled rams, 3 Duroc-Jersey sows, 1 Duroc-Jersey boar.

DEPARTMENTAL NEEDS.

Additional stock is badly needed and new buildings must be provided if the most efficient research work is to be carried through.

Drainage and reclamation work will have to be undertaken if the lands of the stock farm are to be fitted for maximum crop production.

Reports of the Chemists

BY S. K. LOY, HEAD OF THE DEPARTMENT.

My annual report of work done in the Wyoming Experiment Station is confined to three projects, as follows:

W. S. No. 3, Chem. No. 3-a—Vegetable Poisons of the Range, Woody Aster.

W. S. No. 3, Chem. No. 3-b—Vegetable Poisons of the Range, Study of the Toxic Principle.

W. S. No. 3, Chem. No. 9-a—Larkspur.

Owing to teaching duties in the University, my time has been broken up and only at intermittent periods could diligent attention be given to the investigation of poisonous plants.

During the early part of the year I devised a method of collecting the gases evolved when portions of three hundred grams each of finely ground and sieved woody aster and larkspur (*Delphinium geyeri*) were placed in closed vessels and allowed to ferment spontaneously after having been moistened with distilled water containing five-tenths per cent of sulfuric acid.

These experiments seemed to indicate that only carbon dioxide gas is evolved and in large quantity in each case.

Continued experiments of the above, with the addition of pepsin and trypsin ferments, did not give conclusive results and must be repeated.

I next extracted large quantities of the ground material of each plant twice with water carrying small measured amounts of sulfuric acid, pressed out the extract and, after neutralizing nearly all the acid, concentrated the larkspur extract under diminished pressure. I allowed the extract from the woody aster to concentrate by open air evaporation, because previous experience has shown that the application of heat for purposes

of concentration causes decomposition of the extract into products which make identification of the original compound very difficult.

After the extraction of the larkspur with water, I subjected the residue to percolation with cold 95 per cent alcohol until the percolate came clear, concentrated the whole extract and prepared it for detailed examination. I did not extract the woody aster residue with alcohol because I already have a concentrated alcoholic extract of this plant, although it had been obtained by percolation with hot alcohol.

I am of the opinion that the method of extraction and subsequent percolation with cold water and alcohol, respectively, is the better one to follow, because it approximates the conditions under which animals get the plants on the range; and, since the primary purpose of these investigations is to extract and identify the toxic principle, I feel that at least part of my work of former years does not offer the surest means of solving this phase of the problem.

The scheme of using hot solvents was followed after reading the articles of Powers et al. in the *Journal of the Chemical Society* (London), and while that scheme will be applicable in most cases of plant investigations, I am convinced of its impracticability on woody aster and larkspur.

I propose to continue the work of analyzing the aqueous and alcoholic concentrates and to study at the same time the toxic effects of the whole, as well as the fractions obtained from them. This latter work will be in co-operation with the Animal Pathologist, preliminary investigations indicating that the aqueous extract has the poisonous properties.

No work has been done upon W. S. No. 3, Chemistry No. 3-b, "A Study of the Toxic Principle", during the past year, because this project naturally follows W. S. No. 3, Chemistry No. 3-a.

Report of Research Chemist

BY FRANK E. HEPNER.

As in former years, the time of the writer has been divided between Hatch Fund projects and those coming under the Adams Fund. In addition to these lines of work, however, he has had partial supervision of the meteorological observations, and during the absence on leave of the regular professor, a four-hour lecture and laboratory course in Agricultural Chemistry was given throughout the second semester.

Owing to these additional duties, not as much has been accomplished along research lines as could be desired. Another factor contributing toward lessening the amount of research work is the fact that this laboratory is located in the Science Hall, while the chemical stock rooms and all the other chemical laboratories are in the Agricultural Hall. This causes considerable loss of time in carrying material and apparatus back and forth from one building to the other. This factor will doubtless be eliminated before the close of another year, as arrangements are being made to have a room in the Agricultural Hall fitted up for this work.

The oversight of meteorological observations consisted principally in serving as a head to whom the student observer, Mr. Ferdinand Brown, could report in case trouble or accident occurred during the absence of the Acting Director. Mr. Brown having had considerable experience in taking observations, but little supervision or oversight was required or attempted with this phase of the work and no detailed report thereon will be made by the writer. Although ordinarily a great deal of time was not required for this work, occasionally, when trouble with the instruments developed, it required considerable time to locate the cause and provide a remedy.

As a part of the Hatch Fund work, nearly complete analyses of fifteen soil samples were made. These samples are

a portion of those collected in an effort to determine the relationship, if any, existing between the soil composition and that of the plants grown thereon, especially with reference to the nitrogen content. Although this project has been under way for several years, but very little has been done with it, owing to the intervention of other work of more immediate importance, and the prospects at present are that it will be still further delayed.

About twenty-five feed samples were analyzed in connection with cooperative work with the Animal Husbandry Department. The results of these feeding experiments will soon be published in the form of bulletins from that department.

No attempt will be made to describe the work done on Adams Fund projects, except to state that the time was devoted to assisting Mr. Beath in various ways with the different poisonous plant projects he has under way. See his report as to these projects.

A few samples of a miscellaneous character from various sources have been analyzed. The number has, however, been reduced to the minimum, the desire being to limit this class of work as far as possible.

Report of Engineering Chemist

BY K. T. STEIK.

PROJECTS.

One more reaction product was isolated from solutions of sodium chloride in which ordinary Portland cement was immersed. A series of strength tests was completed. The tests were made after the cement had been in solutions of alkali salts for forty months. The results of all work done will be published in bulletin form, and including the reactions of alkali salts on cement and their effects upon the physical strength of cement.

PROJECT NO. 24.

On this project experiments on small samples have been made with the object of finding mixtures that will set. From the results obtained so far, it is evident that it is possible to obtain setting mixtures which greatly vary in their chemical composition. The equipment of the laboratory has been improved, so that in the future it will be possible to prepare larger quantities of these and have them tested also for physical strength in connection with their resistance to chemicals, especially to alkali-salt solutions.

Report of Research Chemist

BY O. A. BEATH.

The research in conjunction with poisonous plants has been centered, largely, upon two species of the larkspur family, viz.: *Delphinium glaucum* and *Delphinium glaucescens.*

Preliminary experiments have been completed in connection with the alkaloids relative to seasonal variation and toxicity, physical form and ultimate composition. Chemically there is a marked contrast to those of European origin.

The tall larkspur (*Delphinium glaucum*) when immature contains a water soluble crystalline complex alkaloid which is very poisonous. Upon hydrolysis a second alkaloid is split off which is much less toxic. It is crystalline and melts sharply at 101° C. At the time of flowering the main alkaloid of the plant undergoes a transition from a crystalline to an amorphous form and becomes less soluble in water and about seven times less toxic than that of the early growth. However, it contains a second alkaloid (amorphous), which is highly poisonous, as illustrated by the fact that one-fifteenth of a grain injected subcutaneously in the ear of a rabbit produced death in less than thirty seconds. This derived alkaloid may be obtained in

one of two ways, either by allowing the original to come in contact with water or by the addition of a mild alkali. A third alkaloid, also amorphous, has been isolated from the original water soluble form. It is scarcely toxic in ordinary doses.

Upon going to seed the tall larkspur does not lose its alkaloids, but they become highly resistive to being broken up into poisonous constituents of a harmful nature. The main alkaloidal complex becomes less soluble in water and much less toxic in itself. The derived poison corresponding to that at at the time of flowering is not obtained so easily, in fact it can be separated only by the use of strong reagents.

The species *Delphinium glaucescens* is quite different chemically from that of the tall larkspur. The alkaloids are crystalline through the entire growth of the plant. Fresh plants, when well crushed and macerated with water, yielded nothing that would affect rabbits. This is probably due to the fact that the alkaloids are not nearly as poisonous as those of the other species. Experiments have shown that it requires about three times more alkaloid to kill than does the active principle of the tall larkspur. The alkaloids of *Delphinium glaucescens* have higher melting points than any other larkspur heretofore studied. A bulletin will be issued during the coming year presenting data in regard to this species.

The available data dealing with *Delphinium glaucum* will will be withheld until a detailed study is made of the early growth, inasmuch as the immature plants have been found to contain active poisons decidedly different in form and toxicity.

Experiments have been made during the past year dealing with methods preliminary to a detailed study of *Lupinus argenteus*. The chemical analysis of the resin has been completed.

The poisonous principle has been isolated from woody aster and a small quantity purified. Its properties are entirely different from those commonly found in poisonous plants on the range. When mixed with an excess of alkali the poison loses its toxicity.

Report of the Parasitologist

BY J. W. SCOTT.

1. RESUME OF WORK IN THE DEPARTMENT OF PARASITOLOGY FOR 1916-1917.

The Transmission of Swamp Fever in Horses.

Last year there was discovered an apparently natural method of transmitting swamp fever by means of the stable fly, *Stomoxys calcitrans.* Additional, carefully planned experiments have further verified this discovery. In one cage three healthy horses were kept with three horses that had the disease, both being exposed to the stable flies in this cage; two out of three of the healthy horses took the disease. In another cage without stable flies, two well horses were kept with infected horses, and neither one took the disease. The circumstantial evidence, therefore, is very strong for believing that at least one of the natural methods of the transmission of swamp fever is by means of *Stomoxys calcitrans.* Other experiments, with negative results, have shown that the disease is probably not transmitted by means of the mosquitoes of this region. Recent German writers have put forward the hypothesis that infectious anemia, or swamp fever, as it is commonly called in this country, is produced by a secretion from bot-fly larvae. Certain tests have shown, under the conditions of our experiments, that the disease was not produced by this means. Our work confirms the general inference recently drawn by the Japanese Commission from the results of pasturing experiments, though they believed that other biting flies, and probably not the stable fly, were responsible for the transmission of swamp fever. It is believed that work has advanced far enough so that we may give certain general directions in regard to how to control the disease.

Life Cycle of Taenia (Moniezia) expansa.

The experiments done during the summer of 1914 were repeated in 1915. However, the results were all negative, in spite of the fact that the conditions were apparently more favorable than the previous year. The results neither affirm nor disprove the work of 1914, so more experiments will be necessary to prove a natural method of transmission. Other experiments resulted as follows: (1) Lambs did not become infected as the result of being fed ripe proglottids; (2) lambs did not become infected as the result of drinking from aquaria in which ripe proglottids had been scattered; (3) a lamb did not become infected as the result of eating grass raised in aquaria containing snails, where ripe proglottids had been scattered; (4) lambs did not become infected from eating grass grown on damp earth where ripe proglottids had been scattered, this being true whether the grass was grown near or removed from water; and (5) a lamb did not become infected with tapeworms as the result of eating certain insects that had been kept some time in a vivarium where proglottids had been scattered. Other experiments will be used during the ensuing year.

Life Cycle of Thysanosoma actinioides.

Our work has further verified the conclusion that *standing water, or at least a swampy area, is a necessary condition for infection.* Another series of experiments has given us no positive information in regard to the life cycle of *Thysanosoma*, though the negative results are interesting and may help us in finally solving the life history. The results obtained appear to vouchsafe the following conlusicons: (1) Lambs do not become infected by eating pond snails that have been exposed to ripe proglottids; (2) lambs do not become infected either through grass or water, from aquaria containing snails which have been exposed to ripe proglottids; (3) lambs cannot be infected by feeding them ripe proglottids; (4) lambs do not become infected from eating grass from aquaria, or from damp

ground, where infective feces have been scattered, this being true whether snails are present or not; (5) lambs do not become infected by eating certain insects that have been exposed to infective sheep feces.

The Life History of Sarcocystis tenella.

We have been more fortunate with our results on this project. The negative results of the year before led us to plan a new series of experiments based on the hypothesis that the sheep is not the definitive host of *Sarcocystis tenella.* Without going into details, we have obtained the following general results:

(1) *Lambs may become infected with the sarcocystis by eating grass.*

(2) *Lambs may become infected by eating certain kinds of insects.*

(3) Lambs do not become infected by eating certain other kinds of insects.

(4) Lambs were not infected by drinking from aquaria in which were placed killed insects which were supposedly infective.

(5) A lamb was not infected by drinking from an aquarium in which had been placed infected heart muscle.

These results are so gratifying that it is believed that we are now in a position to work out the life history in the near future.

II. SUGGESTIONS IN REGARD TO THE FUTURE DEVELOPMENT OF THE WORK IN PARASITOLOGY.

No additional problems will be undertaken by the Department of Parasitology in the coming year. With our present facilities and available help, we could not start work on any new projects without in a degree neglecting the work on problems already started. There are, however, a number of important parasites in Wyoming on which work could, and

should, be started in the near future. I may mention only a few of the more important ones:

(1) The severe boil-like sore, said to be produced by the bite of the Deer-fly (*Chrysops*), should be studied, and its exact nature and cause determined.

(2) Rocky Mountain Spotted Fever is becoming more widespread, more prevalent, and more virulent in Wyoming. The exact source of the disease is unknown, and its control should be studied.

(3) Practically nothing is known of the mosquitoes of Wyoming, or of their relations to man and animals.

(4) There are hundreds of colts and calves lost each year from a mysterious disease, or diseases, in the northern part of the state. This is perhaps a problem for the Veterinarian, but parasites may possibly be involved.

(5) Work should be started toward developing a serum for swamp fever. This should be done conjointly with the Veterinarian.

Many other problems could be started, all worthy of our best efforts, but these examples are enough to show the important need of work in this department.

Report of the Acting Veterinarian

BY J. I. KIRKPATRICK.

Veterinary Project No. 1, Vegetable Poisons of the Range, in co-operation with Mr. O. A. Beath, Research Chemist. Extensive work has been carried on in determining the toxicity and the nature of the toxic principle of the mountain larkspur, *Delphinium sub-alpinum.* Water extracts of the various portions of the plant, as stems, leaves, flowers, and seeds, have been given to rabbits by stomach tube injection. Also alcoholic and chloroform extracts of the active alkaloidal principle of the leaves of the larkspur have been injected with gratifying results. For results obtained refer to Mr. Beath's detailed report. Further work in determining the nature of the toxic principle, its effect on vital organs of the body, the discovery of an antidote for the same, will be attempted in the immediate future.

Veterinary Project No. 4, Transmission of Swamp Fever, in co-operation with Dr. J. W. Scott. Many samples of blood have been drawn from swamp fever patients and misroscopically examined. The purpose of this work is to determine the percentage of swamp fever patients usually affected with pernicious anemia. This condition is indicated by the red corpuscular content of the blood. A marked diminution in the number of red corpuscles per unit volume is indicative of the degree of anemic condition present. The work so far with one exception shows that the red corpuscular content of the bloods ranges from a very small change from normal to a decrease of over seventy per cent per unit volume. The one case mentioned seems to show an increase in the corpuscular content, or perhaps is only due to a decrease in the plasmic content of the blood. This work is in operation at the present time.

Report of the Wool Specialist

BY J. A. HILL.

The experimental work of the Wool Department during the past year consisted of work on two projects. One of these was "The Regain of Unwashed Wool". In it the problem studied was whether or not the moisture content of the natural impurities of unwashed wool responded more readily to moisture changes of the surrounding air than does the moisture content of the pure wool that remains after these natural impurities are removed. Enough work was done on this project to make it clear that the yolk, that is to say, the mixture of wool-fat and dried perspiration, which is found in all unwashed wool, shows greater moisture changes in response to moisture changes of the surrounding air than does the pure fiber itself. On the other hand, the mixture of sand and dust that is often present in large quantities in our wools from the range states is much less sensitive to changes of atmospheric moisture content than is the pure fiber. Hence, in order to show the bearing these results have on the practical problems of the wool trade, it may be said that, in sending wool from the dry climate of the western states to the moisture-laden atmosphere of the Atlantic seaboard, the larger the proportion of sand and dust it contains the less will be the relative gain in weight due to increased moisture content; but the larger the proportion of yolk in the unwashed wool the greater will be the relative increase in moisture content. As the work on this project is extended so as to include more and more measurements obtained by methods more and more refined, it should be possible to state the laws of the change of moisture content in unwashed wool with more and more exactness until it is possible to say that they may be expressed of one or two simple formulae.

The other experiment worked on during the year was, "The Effect of Moisture Content Upon the Strength of Wool Fiber." Work done in preceding years had made it apparent that as the moisture content of the fiber decreased from saturation to some point not far short of absolute dryness, the strength of the fiber increases. Owing to difficulties connected with keeping the moisture of each fiber under exact control until the instant it is broken very little progress was made. Some plans for moisture control were tried and found unworkable. The results of many measurements, where the moisture content of the fibers were known only approximately, gave additional verification of the theories based on the results of the work of preceding years, but on the whole there was very slight progress.

Meteorological Summary

FERDINAND BROWN, OBSERVER.

The favorable weather which continued during the fall of 1914 changed in January, 1915, to a period of storms. The total precipitation for the month was more than five times normal, while the mean temperature was 2.5 degrees below the twenty-year mean. (Wyo. Agr. Exp. Station Bul. No. 100, 1913, p. 36.)

February was somewhat warmer than normal, with a precipitation of nearly three times the twenty-year mean. Notwithstanding the high precipitation, the percentage of sunshine was far above normal, due to the fact that there were only four storms during the month of any consequence and the principal portion of the total precipitation for the month came in one day.

March was a cold, stormy month. The mean temperature was lower than for the preceding month, while the precipitation was double of that of February. Freezing weather continued throughout the month.

Stormy weather continued throughout April, with a slight excess of precipitation, but with a rising temperature, so that the mean temperature for the month was 1 degree higher than for any April for which there is record at Laramie.

May was backward. The last killing frost occurred the 28th of the month. The precipitation was somewhat above normal.

The cool weather continued into June and July, with a slightly sub-normal precipitation.

August continued cool, with a slight excess of precipitation, while September continued about normal. The wind records for these two months shows a greatly sub-normal velocity, total mileage being less than eight thousand for this

period. A very light frost occurred the night of September 9, but no damage was done.

The first killing frost occurred October 3, which is much later than usual. Crops were harvested in excellent shape and threshing was uninterrupted.

Plowing upon the Station farms continued until the middle of November.

December was a normal month, with a slight excess of precipitation.

The mean temperature, because of the cool spring and summer, was sub-normal. The total precipitation for the year was 2.7 inches above the twenty-year mean. There was much less wind than usual. Only one month approached the normal wind velocity.

The year may be characterized as being a good one for the stockmen. The range was in good condition; the grasses cured well, giving excellent winter feed for stock; and the snows were not excessive.

SUMMARY FOR 1915.

Maximum temperature during the year: 84°, July 14.
Minimum temperature during the year: —14°, January 16.
Greatest daily range: 42°, March 22.
Least daily range: 4°, April 23.
Highest barometer: 23.404 inches, July 20.
Lowest barometer: 22.453 inches, November 24th.
Greatest velocity of wind per hour: 43 miles N. W., 1 p. m. Nov. 19.
Greatest number of miles in one day: 633 miles, November 23.
Least number of miles in one day: 24 miles, February 23.
Mean daily distance: 207.5 miles.
Mean hourly distance: 8.6 miles.
Date of light summer frost: September 9.
First killing frost: October 3.
Highest dew point: 71°, July 17.
Lowest dew point: —14°, December 27.
Highest relative humidity: 100 per cent, January 5.
Lowest relative humidity: 27 per cent, July 12.
Greatest precipitation for a single storm: 0.76 inch, February 12.
Number of days on which .01 inch or more precipitation fell: 94.
Total precipitation for the year: 12.92 inches.

METEOROLOGICAL SUMMARY, 1915, BY MONTHS.

MONTHS	Means									Wind				Extreme Temperatures			
	Barometer	Temperatures			Dew point	Relative humidity, per cent	Vapor pressure, inches	Precipitation, inches	Sunshine, per cent	Total miles	Average daily distance	Prevailing direction	Average hourly velocity in miles	Highest degrees F.	Date	Lowest degrees F.	Date
		Max. F.	Min. F.	Mean F.													
January	22.965	31.3	8.2	19.7	11.9	73.8	.0749	1.36	80.1	6,582	212.3	S. E.	†8.8	48	3	—14	16
February	22.928	38.1	16.2	27.1	18.6	79.1	.0828	0.82	92.5	5,627	200	S. E.	8.3	52	9	7	15
March	22.859	36.2	15.1	25.6	20.6	82.9	.1060	1.70	84.6	5,991	193	S. E.	8.0	52	22	—3	6
April	23.055	51.3	34.1	42.7	35.2	80.4	.2100	1.30	80.3	6,732	224.4	S. E.	9.3	68	28	25	1
May	22.950	54.3	32.1	43.2	37.1	79.1	.2320	1.91	86.4	8,602	277.4	N. E.	11.5	74	13	17	2
June	23.074	62.2	40.1	51.1	45.6	77.7	.3210	1.05	71.7	8,534	284	S.	11.8	80	25	28	7
July	23.175	72.2	48.2	56.1	50.0	63.6	.3760	1.20	91.2	7,254	234	S. E.	9.7	84	14	30	14
August	23.186	69.5	45.1	57.3	46.3	60.0	.3210	1.13	82.9	4,607	148	S.	6.1	81	31	40	2
September	23.080	62.2	39.2	50.7	40.6	66.6	.2620	0.89	82.5	3 131	104	S. E.	*4.3	78	1	31	14
October	23.145	51.4	32.0	43.2	30.2	69.6	.1670	0.87	81.9	6,495	209	S. W.	8.7	68	9	13	7
November	22.996	40.3	22.0	31.1	22.6	74.2	.1230	0.16	54.6	8 684	289	S. W.	12.0	60	4	5	28
December	22.941	32.6	11.3	21.9	14.6	77.4	.0900	0.53	60.9	3,591	115	S. W.	4.8	50	6	—13	28
Sums	276.354	604.6	343.6	474.1	373.3	884.4	2.3657	12.92	949.6	75,831	2490.1		103.3				
Means	23.029	50.3	28.6	39.4	31.1	73.7	.1971	1.08	79.1	6 319	207.5	S. E.	8.6				

*Out of order 7 days.
†Out of order 6 days.

METEOROLOGICAL SUMMARY, 1915, BY MONTHS—(Continued)

	Barometer, inches				Temperature range, degrees F.				Dew point, degrees F.				Relative humidity, per cent				State weather, No. days			Wind, miles				Precipitation, inches			
	Highest	Date	Lowest	Date	Greatest	Date	Lowest	Date	Highest	Date	Lowest	Date	Highest	Date	Lowest	Date	Clear	Partly cloudy	Cloudy	Greatest	Date	Least	Date	Highest one storm	Date	Total snow	Days .01 inch precipitation
January	23.198	10	22.501	30	36	21	12	10	28	12	11	22	100	5	49	1	6	25	0	424	19	123	27	0.48	6	13.6	7
February	23.288	6	22.542	3	38	15	8	21	32	2	10	5	100	27	46	9	17	11	0	526	13	24	23	0.76	12	8.2	4
March	23.362	21	22.701	29	42	22	10	2	38	23	2	4	100	3	53	10	8	23	0	508	22	59	1	0.48	22	17.0	14
April	23.242	28	22.648	31	29	28	4	23	49	28	20	2	100	7	52	20	15	15	0	401	30	122	25	0.70	23	3.2	8
May	23.151	12	22.608	1	36	13	5	1	58	13	19	2	100	1	55	16	19	12	0	573	18	67	31	0.72	1	7.5	9
June	23.256	14	22.807	2	36	25	8	1	61	20	27	7	100	1	42	18	21	9	0	501	12	140	27	0.32	3	Trace	10
July	23.404	20	22.894	9	36	11	11	15	71	17	33	4	95	2	27	12	20	11	0	411	19	64	20	0.66	27	0	9
August	23.400	28	23.088	31	38	30	10	8	60	10	26	29	100	8	34	29	13	18	0	269	1	81	10	0.42	7	0	10
September	23.284	17	22.708	13	41	9	9	25	61	22	25	14	100	11	37	1	13	16	1	293	11	39	7	0.44	3	0.5	9
October	23.338	8	22.840	10	39	8	5	18	48	9	11	7	100	11	40	26	22	8	1	368	10	124	8	0.44	11	6.7	4
November	23.198	3	22.453	24	30	29	5	30	39	6	5	28	100	30	45	1	8	17	5	633	23	72	28	0.03	16	0.8	5
December	23.277	1	22.473	29	40	25	9	15	34	4	—14	27	100	15	47	20	10	17	4	331	20	51	4	0.22	23	5.3	5

INDEX